TECHNICAL REPORT

CISPR 16-4-1

2003

AMENDMENT 2
2007-04

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Amendment 2

Specification for radio disturbance and immunity measuring apparatus and methods –

Part 4-1:
Uncertainties, statistics and limit modelling – Uncertainties in standardized EMC tests

Reference number
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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:

DTR	Report on voting
CISPR/A/713/DTR	CISPR/A/729/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 maintenance result date indicated on the IEC web site 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- withdrawn,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.

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2 Normative references

Add the following new references:

CISPR 16-1-4:2007, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Ancillary equipment - Radiated disturbances*

CISPR 16-2-3:2006, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements*

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3 Terms and definitions

Replace the existing heading of Clause 3 by the following:

3 Terms, definitions, and acronyms

Add new subclause 3.1 as follows, and renumber terms 3.1 to 3.20 as 3.1.1 to 3.1.20:

3.1 Terms and definitions

Add, on page 14, the following new subclause:

3.2 Acronyms

AF antenna factor

EUT equipment under test

GUM *ISO/IEC Guide to the expression of uncertainty in measurement*

ILC interlaboratory comparison

LPDA log-periodic dipole array

MIU measurement instrumentation uncertainty

OATS open-area test site

RRT round-robin test

SAC semi-anechoic chamber

SCU standards compliance uncertainty

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8 Radiated emission measurements

Replace the existing title and text of Clause 8 by the following:

8 Radiated emission measurements using a SAC or an OATS in the frequency range of 30 MHz to 1 000 MHz

8.1 General

8.1.1 Objective

This clause provides information and guidance for the determination of uncertainties associated with measurement equipment and the measurement method used for radiated emission measurements in the frequency range of 30 MHz to 1 000 MHz in a SAC or on an OATS. Furthermore, a rationale is provided for the various uncertainty aspects described in several parts of CISPR 16 that are related to the radiated emission measurement method (see Clause 7 of CISPR 16-2-3).

In CISPR 16-4-2, the uncertainty considerations for SAC/OATS-based radiated emission measurements are limited to measurement instrumentation uncertainties (MIU). This part addresses all uncertainties that are relevant for compliance testing, i.e. the standards compliance uncertainty (SCU), which also includes the MIU.

The rationale for the methods of uncertainty estimation provided in this Clause 8 is intended to serve as background information for the parts of CISPR 16 that are related to the SAC/OATS-based emission measurement method. This background information may be used by the CISPR subcommittees to improve the existing standards as far as uncertainties are concerned. In addition, this clause provides information for those who apply the radiated emission measurement method and who have to establish their own uncertainty estimates.

8.1.2 Introduction

Clause 8 provides information on the uncertainties associated with the SAC/OATS-based radiated emission measurement method as described in CISPR 16-2-3. The uncertainty estimates for the SAC/OATS radiated emission measurement method described in CISPR 16-4-2, or for example in LAB 34 [11], address only some of the uncertainty components present in actual compliance tests performed in accordance with CISPR 16-2-3. Uncertainty estimates in the aforementioned documents account only for the measurement instrumentation uncertainties (MIUs), whereas uncertainties due to the set-up of the EUT including its cables, and due to the measurement procedure itself, are not taken into account. In this clause, all uncertainty sources that are relevant for the measurement uncertainty of the compliance test, termed as the standards compliance uncertainty (SCU), are considered. One basic assumption for these SCU estimations is that the EUT does not change. In other words, the uncertainty of the SAC/OATS radiated emission measurement method is considered based on using the same EUT as measured by different test laboratories. The laboratories will use different measurement instrumentation, a different test site, different measurement procedures, and different operators. Often the laboratories may also apply different measurement set-ups or different EUT operating modes. The latter EUT-related sources of uncertainty may become significant, and can contribute to poor reproducibility.

The uncertainty estimation described in this clause is done in accordance with the basic considerations on uncertainties in emission measurements given in Clause 4.

8.2 Uncertainties related to the SAC/OATS radiated emission measurement method

This subclause describes the preparation of the uncertainty estimates for the SAC/OATS-based radiated emission measurement method described in Clause 7 of CISPR 16-2-3. For reference, a schematic overview of the radiated emission measurement method is given in Figure 8-1. This figure shows an EUT set up on a positioning table in a SAC. The receive antenna measures the sum of the direct and reflected emission from the EUT.

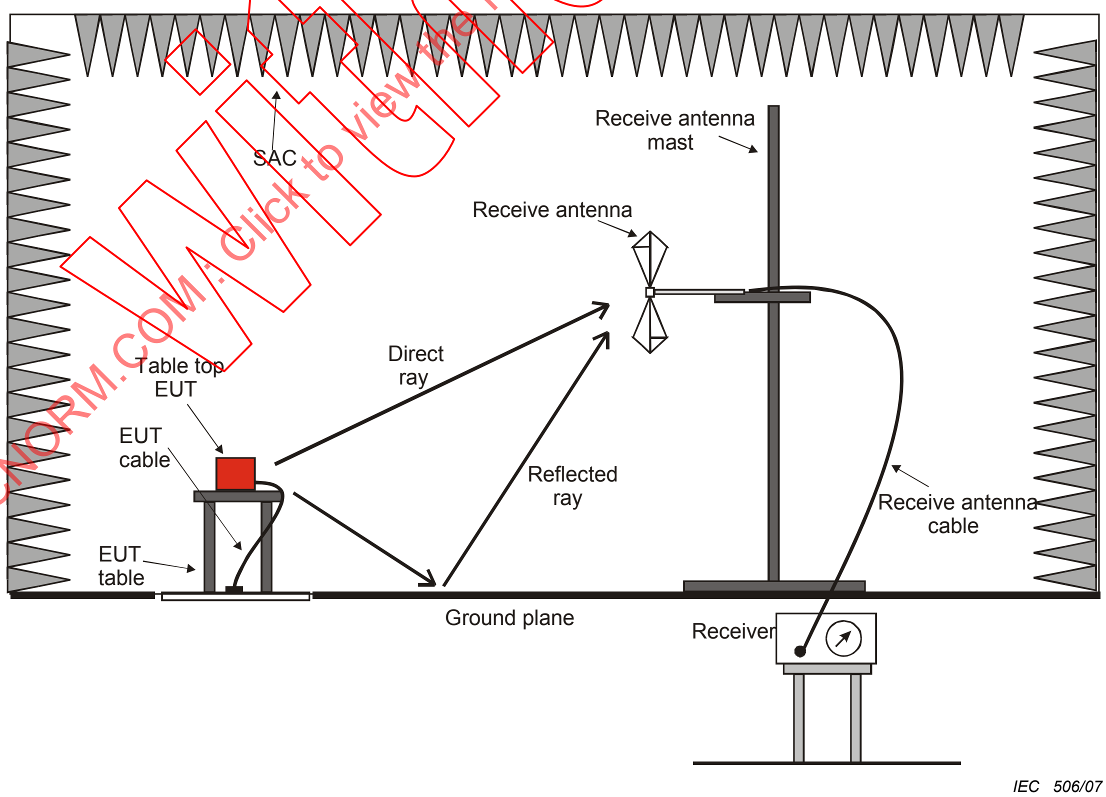

Figure 8-1 – Schematic of a radiated emission measurement set-up in a SAC

8.2.1 The measurand

Previously, the measurand for the SAC/OATS-based radiated emission measurement method in CISPR 16-2-3 was only incompletely defined. In Clause 4 of CISPR 16-1-4, which covers the frequency range 9 kHz to 18 GHz, a reference antenna (balanced dipole) was specified in the range 30 MHz to 300 MHz. For convenience, this measurand was called the reference electric field strength (E-field), i.e. the E-field measured by the CISPR reference antenna. In the frequency range 300 MHz to 1 000 MHz, a reference antenna was not defined, and the measurand is the electric field strength.

Recently work was begun in CISPR/A to implement E-field as the quantity to be measured over the frequency range of 30 MHz to 1 000 MHz, with an amendment under development at the time of writing.

In this subclause it is assumed that the quantity to be measured is the E-field. However, this is not a complete description of the measurand, because as described in the ISO GUM the measurand definition also requires statements about the influence quantities.

From a metrological viewpoint, a more appropriate description of the measurand associated with the SAC/OATS-based radiated emission measurement, is as follows:

The quantity to be measured is the maximum field strength emitted by the EUT as a function of horizontal and vertical polarisation and at heights between 1 m and 4 m, and at a horizontal distance of 10 m from the EUT, over all angles in the azimuth plane. This quantity shall be determined with the following provisions:

a) the frequency range of interest is 30 MHz to 1 000 MHz;

b) the quantity shall be expressed in terms of field strength units that correspond with the units used to express the limit levels for this quantity;

c) a SAC/OATS measurement site and positioning table shall be used that complies with the applicable CISPR validation requirements;

d) a CISPR-compliant EMI receiver shall be used;

e) the application of alternative measurement distances, such as 3 m or 30 m rather than the nominal distance of 10 m (see 8.2.3.3a), is considered to be an alternative measurement method; correlation factors shall be used to translate results obtained at these measurement distances to 10 m results (see 8.2.3.3a for the consequences in terms of uncertainties);

f) the measurement distance is the horizontal projection onto the ground plane of the distance between the boundary of the EUT and the antenna reference point;

g) the EUT is configured and operated in accordance with the CISPR specifications;

h) free-space-antenna factors shall be used.

The measurand E is derived from the maximum voltage reading V_r by using the free-space antenna factor AF:

$$E = V_r + L_c + F_A + \sum_i C_i^{IQ} \qquad (8\text{-}1)$$

where

E	is the field strength in dB(μV/m) as described in the measurand description;
V_r	is the maximum voltage reading in dB(μV) using the procedure as described in the measurand description;
L_c	is the loss in dB of the measuring cable between antenna and receiver;

F_A is the free-space antenna factor 1) of the receive antenna in dB(m^{-1});

$\sum_i C_i^{IQ}$ is the sum of the correction factors C_i^{IQ} that may be applicable for the various influence quantities as described in 8.2.3.

8.2.2 Uncertainty sources

This subclause summarises the sources of uncertainty associated with the SAC/OATS-based measurement method. From Equation (8-1) it can be seen that the uncertainty is determined by the uncertainty of the measured voltage, the uncertainty of the cable loss, and the uncertainty of the antenna factor.

The uncertainty of the measured voltage is determined by the uncertainties induced by the EUT, the set-up, the measurement procedure, the measurement instrumentation and the environment. Figure 8-2 gives a schematic overview of all the relevant uncertainty sources. This fish-bone diagram indicates the categories of uncertainty sources that contribute to the overall uncertainty of the measurand. An important set-up uncertainty source is the reproducibility of the set-up of the EUT.

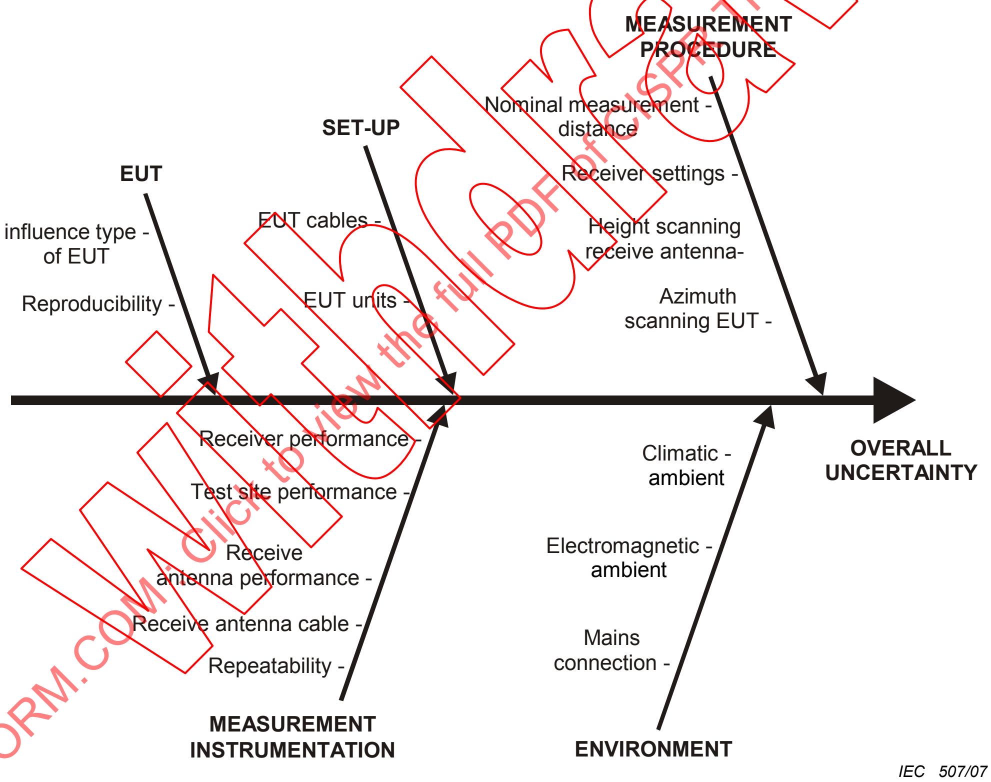

Figure 8-2 – Uncertainty sources associated with the SAC/OATS radiated emission measurement method

1) Free-space antenna factors are used as a figure of merit for the antenna. It should be noted the field strength is not measured in a free-space environment but over a ground plane. See 8.2.3.5 h) for further information.

8.2.3 Influence quantities

For most of the qualitative uncertainty sources given in Figure 8-2, one or more influence quantities can be used to “translate” the uncertainty source in question. Table 8-1 shows the relationship between the uncertainty sources and the influence quantities. If an influence quantity cannot be identified, the original uncertainty source will be used in the uncertainty estimate. For each of the uncertainty sources and influence quantities, details are provided below.

NOTE The uncertainty sources and influence quantities terms used in this subclause and in the remainder of Clause 8 may deviate from similar terms used in CISPR 16-4-2. This is justified for the following reasons: a) Some of the influence quantities are specifically applicable for SCU, and are not applicable for the MIU-only estimates of CISPR 16-4-2; b) Some of the influence-quantity terms used in CISPR 16-4-2 are not quantified or are not clearly identified. For instance the term “site imperfection” is a qualitative term used in CISPR 16-4-2. The term “NSA deviation” used in Table 8-1 is more appropriate because it reflects a specific and well-known quantity. Furthermore, the term ”noise floor proximity” is not clearly defined, while the term “signal-to-noise ratio” is a well-known and quantifiable term.

Therefore it is intended to harmonise with the terms used in this document in future maintenance of CISPR 16-4-2.

Table 8-1 – Influence quantities for the SAC/OATS radiated emission measurement method associated with the uncertainty sources of Figure 8-2

Subclause no.	Uncertainty source	Influence quantity
8.2.3.1	**EUT-RELATED**	
a)	Influence of type EUT on other uncertainty sources	Size of EUT
b)		Type of disturbance
c)	Reproducibility of EUT	Product sampling
d)		Modes of operation
8.2.3.2	**SET-UP-RELATED**	
a)	EUT set-up	Layout of EUT unit(s) and cable(s)
b)		Termination of cable(s)
c)		Measurement distance tolerance
d)		EUT height above ground plane tolerance
8.2.3.3	**MEASUREMENT-PROCEDURE-RELATED**	
a)	Nominal measurement distance	Nominal measurement distance
b)	Receiver settings	Receiver settings
c)	Height-scanning of receive antenna	Height-scanning step size
d)		Start and stop position tolerance
e)	Azimuth-scanning of EUT	Azimuth step size
8.2.3.4	**ENVIRONMENT-RELATED**	
a)	Climatic, ambient	Temperature and humidity tolerances
b)	Electromagnetic ambient signals	Signal-to-ambient-signal ratio
c)	Mains connection	Mains voltage variation
d)		Application of mains coupling devices
8.2.3.5	**MEASUREMENT-INSTRUMENTATION-RELATED**	
a)	Receiver performance	Receiver accuracy
b)		Mismatch at the receiver input
c)		Measuring system reading
d)		Signal–to-noise ratio
e)	Test-site performance	NSA deviation
f)		EUT positioning table
g)		Influence receive-antenna mast
h)	Receive-antenna performance	Free-space antenna factor uncertainty
i)		Type of receive antenna (directivity)
j)		Antenna-factor height dependence
k)		Antenna-factor frequency interpolation
l)		Antenna phase-centre variation
m)		Antenna unbalance
n)		Cross-polarisation performance
o)	Receive antenna cable	Cable loss uncertainty
p)		Mismatch [a]
q)	Measurement system repeatability	Measurement system repeatability

[a] When a single cable is used, there are two sources of mismatch between the antenna and the receiver:

a) between the antenna and the cable;

b) between the cable and the receiver (=mismatch at receiver input).

If a test lab uses several cables to interconnect the antenna and the receiver, additional mismatches may be present. In the estimation of MIU, typically only a single mismatch influence quantity is included.

8.2.3.1 EUT-related influence quantities

a) Size of EUT

Various influence quantities depend on the type of the EUT, i.e. large EUTs, small EUTs, EUTs with single or multiple attached cables. The electromagnetic behaviour of these different EUT types may cause different contributions to uncertainty. Influence quantities that are affected by the size of the EUT are included as part of the EUT set-up-related influence quantities in 8.2.3.2. For the EUT-related uncertainty source, no specific uncertainty value will be assigned to the size of the EUT, to avoid double counting of uncertainties. Instead, the size of the EUT shall be considered as an influence quantity for the uncertainties of the set-up-related uncertainty sources discussed in 8.2.3.2.

b) Type of disturbance

The type of the disturbance (broadband, narrowband or intermittent) radiated by the EUT may affect the magnitudes of the uncertainties induced by the receiver and by the measurement method applied (e.g. probability of intercept of broadband signals).

c) Product sampling (if applicable)

This influence quantity is especially important if the measurement is repeated by the manufacturer for quality assurance reasons, or if the 80 %/80 % rule is to be applied. If the manufacturer performs a type test, the manufacturer may repeat the measurement using different samples of the same type of EUT. In case of market surveillance that involves measurements on different samples by another test laboratory, the 80 %/80 % rule may also be applied.

d) Modes of operation of the EUT

During the measurement, meaningful modes of operation shall be selected such that representative and worst case radiated emissions are obtained. In cases that the modes of operation are not specified, different operators and/or test laboratories could select different modes in conjunction with different receiver settings and scan speeds, which may induce significant reproducibility uncertainties, and therefore affecting SCU.

8.2.3.2 Set-up-related influence quantities

a) Layout of EUT unit(s) and cable(s)

Despite the specification of the EUT set-up in product standards, this influence quantity may cause significant uncertainties when different operators and different test laboratories configure a given EUT. Especially for an EUT that consists of several enclosures and interconnecting cables, the uncertainty due to the many degrees of freedom allowed for setting up the EUT may be significant. This influence quantity contributes to the SCU. Results of the CISPR/A RRT in the frequency range 30 MHz to 300 MHz [f3] revealed that the uncertainty induced by the set-up for the specific EUT was approximately 7 dB. The uncertainty associated with the set-up of an EUT depends largely on the type of the EUT. Table 8-2 provides qualitative guidance for the set-up uncertainty as a function of EUT type. Above 200 MHz, the effect of different cable layouts is reduced.

Table 8-2 – Relation between and type of EUT and set–up-related uncertainties

Type of EUT	Set-up uncertainty
Table-top battery fed	Very low
Table-top: single unit, single cable to mains	Low
Table-top: multiple units, multiple cables to mains and auxiliary equipment	High
Floor-standing equipment, single cable to mains	Low
Floor standing equipment, multiple cables to mains and auxiliary equipment	High

b) Termination of cable(s)

Different test laboratories may use different cable decoupling devices, such as CDNs, decoupling transformers, absorbing clamps, LISNs, or some combination thereof, or none. These different decoupling devices affect the common-mode impedance, as seen from the EUT, and may produce different disturbance levels. Disturbance levels also depend on the category of the EUT (mains connection with or without protective earth) and on the type (dimension) of EUT (see references [f4], [f2] for further details). A summary of the expanded uncertainty results for the EUTs of [f2] is given in Figure F.1 of Annex F. Between 30 MHz and 200 MHz, application of different termination devices, such as common-mode absorbing device (CMADs), CDNs or LISNs, may cause a significant variation of results, i.e. 10 dB to 20 dB expanded uncertainty below 100 MHz. This influence quantity may be significant when estimating the SCU, especially below 200 MHz.

c) Measurement distance tolerance

The uncertainty in measurement distance arises from uncertainties due to determination of the perimeter of the EUT, distance measurement, and antenna mast rigidity. No correction is made for errors in the measurement distance between the perimeter of the EUT and the reference point of the receive antenna. Typically a measurement distance tolerance of ± 10 cm can be expected, the effect of which is largest at small measurement distances. The maximum uncertainty varies as a function of nominal measurement distance and as a function of EUT height [27]. For table-top EUTs at 3 m measurement distance, the resulting uncertainty is approximately ± 0,4 dB (rectangular distribution). In practice, this maximum uncertainty is often estimated from the field variation of a source in free space at a certain nominal distance. It should be noted that oftentimes for larger measurement distances, the free-space estimate does not provide a conservative value [27]. See Table E.3 and Table E.4 in Annex E for uncertainty values as a function of measurement distance.

d) EUT height above ground plane tolerance

The uncertainty of the standard EUT height above the ground plane, i.e. 0,8 m for table-top EUTs, is typically ± 1 cm. The resulting effect is a change in the interference (radiation) pattern at the measurement location. Depending on the step size of the height scanning of the receive antenna, this influence will induce an uncertainty of the measured maximum electric field strength, the effect of which is largest at small measurement distances. This uncertainty has an effect mostly at frequencies where the maximum field strength is measured at either the lower or upper limits of the antenna scan height (typically at the lower limit, near 1 m), provided that the height-scan step size is sufficiently small. The uncertainty varies as a function of measurement distance, polarisation, and frequency range, and as a function of nominal height of the EUT [27]. It is shown in [27] that the effect of a 1 cm height tolerance is quite significant (± 0,5 dB) for a nominal EUT-height of 0,4 m. For a table-top EUT (nominal EUT-height of 0,8 m) and 3 m measurement distance, the height uncertainty of ± 1 cm causes an uncertainty of approximately ± 0,3 dB (rectangular distribution). See Table E.3 and Table E.4 in Annex E for uncertainty values as a function of measurement distance.

8.2.3.3 Measurement procedure-related influence quantities

a) Nominal measurement distance

For SAC/OATS-based radiated emission measurements, the nominal measurement distance is 10 m (see definition of measurand in 8.2.1). If an alternative measurement distance is applied, for example 3 m, then a conversion of the 3 m results into emission results expected at the nominal measurement distance of 10 m shall be applied.

NOTE 1 The application of an alternative measurement distance, such as 3 m or 30 m rather than 10 m, is considered to comprise an alternative measurement method. Conditions for the use of alternative measurement methods, including uncertainty considerations, are described in CISPR 16-4-5/TR:2005.

In practice, such conversions are often done assuming that the emission from an EUT at a certain measurement distance may be converted to another distance by applying the free-space field-strength attenuation formula, i.e. 20 dB/decade or 1/*r* behaviour.

NOTE 2 In Ed. 5.2 of CISPR 22 the NOTE in 10.3.1 states that an inverse proportionality factor of 20 dB per decade shall be used to normalize the measured data to the specified distance, for conformity assessment.

However, the exact conversion very much depends on the type of EUT, the actual measurement distances involved, and frequency. Different RRT results (see 8.2.6) confirm that the correlations for a specific EUT do not follow the simplified free-space conversion rule of 20 dB/decade. As an example, Figure F.5 of Annex F shows the actual and free-space converted results from 3 m to 10 m distances for a small table-top EUT, based on results from an RRT [f7], [f8].

The correlation of results obtained from a SAC/OATS 3 m measurement distance to a 10 m measurement distance is done by subtracting 10,5 dB from the results at each frequency. For the example of Figure F.5, the actual correlation factor varies with frequency between 5 dB and 9 dB, and the average correlation factor is 7,6 dB. This correlation factor shall be used as a correction of the results [Equation (8-1)]. Generic correlation factors applicable to any EUT are generally not available. Use of a single correction factor value for the entire frequency range causes an uncertainty that becomes relevant when 3 m and 10 m emission measurement results for the same EUT are compared. Such a comparison can occur in market surveillance situations, for example. Consequently the resulting uncertainty contributes to the SCU. Note also that this influence quantity does not contribute to the MIU, because uncertainty contribution is present even if measurement instrumentation and site effect uncertainties are negligible. The results of Figure F.5 show that use of a correlation factor of 10,5 dB yields overly-compensated results at 10 m. From a compliance determination point of view it may be more appropriate to apply a smaller correlation factor. The selection of the correlation factor determines the resulting uncertainty, as far as the difference in results obtained at different measurement distances is concerned. From the aspect of market surveillance, the difference in results may have less of an impact because it is more important that the measurement data is below the applicable limit in both cases. In this case it might be prudent to apply a conservative correlation factor, e.g. 5 dB.

b) Receiver settings

Some flexibility is provided in the measurement method standards for receiver settings, as performed either manually or under software control. This may lead to uncertainties that are dependent on the type of disturbance (broadband/narrowband or intermittent) emitted by the EUT (see CISPR 16-2-3). Some examples are the sweep time setting, setting of input attenuation, and reference level setting.

c) Height-scanning step size

The height of the receive antenna is varied between 1 m and 4 m. The operator or the measurement automation software establishes the step size for the height variation. The height step size influences the probability of missing the maximum electric field strength at the measurement position. The associated uncertainty also depends on the type of EUT (height above ground plane, polarisation of the disturbance) and on the measurement distance and frequency. The lobe height of the interference pattern is smallest for table-top EUTs at the highest frequency and at the shortest measurement distance of 3 m. Under these conditions, the step-size induced uncertainty will become highest. Below 200 MHz, the associated uncertainty is negligible provided that the step size is less than 25 cm. At higher frequencies (> 200 MHz) the uncertainty may be significant [27]. For example, at a 3 m measurement distance and for a step size of 25 cm, the measured field may be 1 dB lower than the value measured using a near-continuous scan (height step size of 0,01 m). A reduced step size of 10 cm will reduce this deviation to 0,2 dB. The latter figure is what is included in the example uncertainty estimates listed in Annex E (0 dB to -0,2 dB, rectangular distribution, and a correction factor of +0,1 dB). At 10 m and 30 m measurement distances, the step size may be reduced considerably to maintain the same step-size induced uncertainty of +0 dB to -0,2 dB. For EUT heights of 0,4 m above the ground plane, the step-size induced uncertainty is negligible. In general, a continuous height scan minimizes this error contribution. However, with smaller height step sizes, measurement time may increase drastically, because sufficient dwell time at each incremental height is used to accommodate EUT operations.

d) Start and stop position tolerance (height scan)

The uncertainty in height of the start and stop position is typically a few centimetres. Depending on the receive antenna height step size, measurement distance and frequency, this will affect the probability of measuring the maximum electric field strength. This uncertainty is related and similar in nature to the uncertainty-related to EUT height tolerance. This uncertainty is significant at those frequencies where the maximum field strength is measured at either the lowest or the highest positions of the antenna height scan (generally at the lower limit near 1 m). There is an additional uncertainty if the height-scan step size is too large. The uncertainty is largest at the measurement distance of 3 m and in the case of predominantly vertical polarisation of the disturbance source [27]. For a table-top EUT at 3 m measurement distance, and with a receive antenna start-position tolerance of ± 3 cm, the resulting uncertainty is ± 0,6 dB (rectangular distribution). For EUTs at a height of 0,4 m, the resulting uncertainty is ± 0,2 dB. See Table E.3 and Table E.4 in Annex E for uncertainty values as a function of measurement distance.

e) Azimuth step size

The azimuth radiation pattern of an EUT radiating in free space becomes more directive at higher frequencies. However, the ground reflection tends to make the overall azimuth pattern omni-directional again, whereas grating lobes appear in the elevation pattern. The EUT must be rotated in azimuth in order to capture the maximum emission, and thus the azimuth step size and the azimuth start position determine the probability of intercept of the maximum electric field strength within a certain tolerance. The associated uncertainty does not depend on measurement distance. A continuous rotation will minimize this effect.

8.2.3.4 Environment-related influence quantities

a) Temperature and humidity tolerances

These environmental influence quantities are considered to have a negligible impact on the result of the measurement for measurements done in a SAC. If an OATS is used, then depending on the dimensions and shape of the conducting ground plane, the influence of water on the ground plane, the ground properties beyond the ground plane, and wet or dry nearby vegetation may have an impact on site performance. So this influence quantity should be taken into account in the test site performance [see 8.2.3.5 0]. In addition, sensitivity of the measuring equipment (antenna, receiver) to environmental parameters is generally negligible.

The insertion loss of the cable between antenna and receiver varies with temperature. This may cause repeatability problems for OATS measurements. The cable loss should be measured at a temperature close to the temperature at which the emission measurements will be made. The use of white-sheathed cable can reduce short-term variations caused by intervals of direct sunlight and cloud cover.

Similarly, for measurements done at an OATS, direct exposure to sunlight may cause temperature variations within the EUT and consequently variation of the level of radiated emission. This influence quantity will contribute to the SCU. The use of an electromagnetically-transparent shelter (radome) may reduce the impact on the EUT from sunlight irradiation and humidity.

b) Signal-to-ambient-signal ratio

When using an OATS, the ambient levels of radiated emissions from radio transmitters may negatively impact the measurement of radiated emissions at specific frequencies, or even render emissions measurements impossible. The associated uncertainty of the measured disturbances that coincide with the ambient radio frequencies may therefore be significant. In general these ambient signals are not coherent with the measured disturbance, and therefore can be treated as a noise signal. The resulting errors depend on the ratio of the disturbance signal and the ambient signal, and the level of the internal receiver noise [23], [24]. For measurements done in a SAC, the uncertainty due the ambient radiated signals is negligible.

c) Mains voltage variations

The EUT shall be operated using a supply that has the rated voltage of the EUT (see 6.3.4 of CISPR 16-2-3). If the level of disturbance varies considerably with the supply voltage, the measurements shall be repeated for supply voltages over the range of 0,9 to 1,1 times the rated voltage. EUTs with more than one rated voltage shall be tested at the rated voltage that causes the maximum disturbance. Deviations of the mains voltage deviations from the nominal may introduce uncertainties if the level of disturbance power depends on the mains voltage level. The magnitude of this variation will be highly dependent on the type of EUT, and therefore should be evaluated for each EUT. Consequently, this influence quantity will contribute to SCU. However, no specific uncertainty figure can be estimated for this influence quantity.

d) Application of mains decoupling devices

The different mains filters and mains decoupling devices, such as CDNs, decoupling transformers, variacs, LISNs or combinations thereof, used in various laboratories may give rise to different disturbance levels, also depending on the category of EUTs (mains connection with or without protective earth). See also 8.2.3.2 b) about mains connections.

8.2.3.5 Measurement instrumentation-related influence quantities

a) Receiver accuracy

The accuracy can be obtained from the specifications sheet or the calibration certificate of the receiver. If calibration data is not available, or if only verification was performed, i.e. verification that the parameters are within specifications, then the specification values should be used and treated as rectangular-distributed values to calculate the uncertainty. If calibration data is available (i.e. a specific value for each parameter and an associated uncertainty, probability distribution, and confidence level), then this information can be used to calculate the uncertainty contribution. If necessary, the uncertainty for different types of signals/responses may be considered, i.e. CW accuracy, pulse-amplitude response accuracy, and pulse-repetition response accuracy. See also Annex A of CISPR 16-4-2 for detailed considerations about the accuracy of the receiver.

b) Mismatch at the receiver input

Mismatch uncertainties will occur due to the mismatch of the measuring cable connected to the receiver. This mismatch uncertainty depends on the receiver input impedance, the input attenuation setting of the receiver, the antenna impedance, and the impedance and attenuation properties of the measuring cable, which are functions of frequency. See also Annex A of CISPR 16-4-2 and [f4]. The return loss of biconical and hybrid antennas generally gets worse at low frequencies, such that an attenuator typically is used between the antenna and the cable to reduce VSWR to less than 2,0 to 1 [CISPR 16-1-4, 4.5.2 c)]. The VSWR of the receiver input has a maximum value of 2,0 to 1 (for zero dB input attenuation – which should be avoided, however), and VSWR of biconical and log-periodic dipole array (LPDA) antennas are 4,6 to 1 (maximum 10 to 1 or more) and 2,0 to 1, respectively. The mismatch uncertainty has a U-shaped distribution [25]. Typical values for mismatch uncertainties are +0,9/-1,0 dB below 200 MHz, and ± 0,3 dB between 200 MHz and 1 000 MHz (data taken from [f4], [22]).

c) Measuring system reading

Receiver reading uncertainties depend on receiver noise, display fidelity, and meter scale interpolation errors. The latter should be a relatively insignificant contribution to the uncertainty for measuring systems with electronic displays (least-significant digit fluctuation). However, for analogue meter displays, this latter uncertainty contribution shall be considered.

d) Signal-to-noise ratio

For radiated emission measurements, the receiver noise floor will influence measurement results, especially at the larger measurement distances of 10 m and 30 m. In general, the impact of the noise also depends on the type of noise. Boltzmann (random) noise has far less effect on a signal than does a coherent noise signal. The internal receiver noise is random noise, and the resulting error when measuring a disturbance will depend on the disturbance-to-noise-level ratio [23], [24]. For example, a random noise level of 10 dB below a CW signal causes an error of +0,7 dB on the CW signal, but an unwanted random noise level of 3 dB down causes an error of +1,4 dB. In general, a larger measurement distance will reduce the disturbance-level-to-internal-noise ratio [23]. Also, the use of pre-amplifiers near the antenna will influence the noise floor level. Therefore, it is difficult to give uncertainty estimates as a function of measurement distance due to the internal noise floor level of the receiver. Table E.3 and Table E.4 in Annex E give some typical uncertainty estimates as a function of measurement distance. The proximity of the actual internal noise floor to the applicable emission limit can be used to estimate the resulting error.

e) NSA deviation

The imperfections of a SAC or OATS test site, for example caused by non-ideal absorbing walls or a finite and irregular ground plane, directly affect the result of a radiated emission measurement. The test site imperfections depend on the type of EUT (large, small) and on frequency. The test site performance is quantified by the normalized site attenuation (NSA), wherein the EUT is represented by a transmit antenna of similar type as the receive antenna, and the NSA is evaluated for several positions of the transmit antenna in the test volume. The test site pass/fail criterion for the NSA-deviation is ± 4,0 dB. Note that an NSA measurement includes uncertainty components such as linearity of the receiver, stability of the generator, and uncertainties of the two antenna factors. See also 5.6.3 and Annex F of CISPR 16-1-4. For purposes of this subclause, the intrinsic NSA performance should be used, i.e. the uncertainty of the NSA measurement is subtracted from the NSA results. An example of the uncertainty estimate associated with the NSA-measurement method, including uncertainty contributions from instrumentation, is given in Table 8-3. The resulting expanded uncertainty is ± 2,0 dB. Table 8-4 shows how this uncertainty affects a NSA measurement of a site with an intrinsic (actual) site deviation performance of ± 3,0 dB (rectangular distribution).

Table 8-3 – Example of uncertainty estimate associated with the NSA measurement method, 30 MHz to 1 000 MHz

UNCERTAINTY SOURCES Influence quantities	Uncertainty value (+/-dB)	Probability distribution	Divisor	Standard uncertainty
ANTENNA-RELATED				
Transmit antenna factor uncertainty	1,0	Rectangular	1,73	0,58
Receive antenna factor uncertainty	1,0	Rectangular	1,73	0,58
SETUP-RELATED				
Tolerance measurement distance	0,1	Rectangular	1,73	0,06
Tolerance transmit antenna height	0,1	Rectangular	1,73	0,06
Tolerance start & stop position receive antenna	0,1	rectangular	1,73	0,06
TEST PROCEDURE-RELATED				
Repeatability	0,5	Rectangular	1,73	0,29
MEASUREMENT INSTRUMENTATION-RELATED				
Stability generator	0,1	Normal	2,00	0,05
Linearity receiver/analyser	0,5	Rectangular	1,73	0,29
Mismatch at the input	0,4	U-shaped	1,41	0,28
Mismatch at the output	0,4	U-shaped	1,41	0,28
Measuring system reading	0,1	Rectangular	1,73	0,06
Signal to noise ratio	0,1	Rectangular	1,73	0,06
Combined standard uncertainty				1,01
Expanded uncertainty		Normal	2,00	2,01

Table 8-4 – Relationship between intrinsic and apparent NSA

	Value (+/-dB)	Probability distribution	Divisor	Standard uncertainty
Uncertainty NSA measurement	2,0	Normal	2,00	1,00
Test site deviation (=intrinsic NSA spec)	3,0	Rectangular	1,73	1,73
Combined standard uncertainty				2,00
Expanded uncertainty (= apparent NSA spec)		Normal	2,00	4,00

The calculation of the overall or apparent NSA (NSA including measurement uncertainty) obeys the rules of the uncertainty calculations, because the NSA is also a statistical quantity that varies independently from the NSA uncertainty. In conclusion, a site that complies with the NSA specification ± 4,0 dB has an intrinsic test site deviation of ± 3,0 dB (rectangular distribution). See also 8.2.3.4a) for the impact of weather on OATS performance. If the measured NSA is less than the ± 4dB specification level, then the actual measured (intrinsic) values can be used in the uncertainty estimates thereby to reduce the overall MIU.

f) EUT positioning table

Support tables for EUTs are constructed of wood or other types of non-conducting materials. The dielectric properties of these materials or absorbed moisture may affect the emission results, especially above 200 MHz (see 5.9 of CISPR 16-1-4) for table-top equipment. An estimate of the deviation can be obtained using the measurement method described in 5.9 of CISPR 16-1-4 (rectangular distribution). The impact of low-height support tables used for floor-standing equipment are considered to have a negligible impact, provided that the perimeter of the support table is less than or equal to the EUT perimeter at the base (footprint).

g) Influence of the receive antenna mast

The antenna mast assembly used for the positioning of the receive antenna may also affect the measurement results. If the same antenna mast is in place during the site validation testing, the uncertainty due to the receive antenna mast does not need to be considered separately. However, if a different antenna mast is used during NSA measurements, the effects of the antenna mast used for emission measurements shall be evaluated separately. The resulting deviation shall be included in the uncertainty estimate (see also 5.9 of CISPR 16-1-4:2007).

h) Free-space antenna factor uncertainty

The uncertainty of the antenna factor directly affects the uncertainty of the measurement result [see Equation (8-1)]. In principle, the antenna factor to be used depends on the EUT to be measured and on the test site configuration. This is because the incident field is not a uniform plane wave, incident from a single direction, and in addition the height of the antenna above the ground plane is varied during the measurement. However, it has been demonstrated that on average, the application of free-space antenna factors instead of geometry-specific antenna factors yields results with the lowest uncertainties (see [21]). For this reason, CISPR/A recommends the application of free-space antenna factors as a practical single frequency-dependent figure-of-merit (see future amendment of CISPR 16-1-5). The uncertainty of the free-space antenna factor is listed in antenna calibration reports. Typical expanded uncertainty values for the calibration of free-space antenna factor are ± 1,5 dB (normal distribution, coverage factor $k = 2$).

Apart from the calibration uncertainty, uncertainties associated with the practical simplification that comes from application of the free-space antenna factor shall also be considered. The influence quantities associated with this antenna factor simplification are the type of receive antenna (directivity), and the antenna height dependence. These influence quantities are discussed in the following two list items.

i) Type of receive antenna (directivity)

The free-space antenna factor used as a simplified single figure-of-merit is not sufficient to give an accurate conversion of the measured voltage to electric field strength at the position of the antenna phase centre. In practice, various types of antennas may be used, ranging from tuned dipole antennas to broadband antennas. Different types of antennas will average the incident field strength differently. Instead of this “spatial” viewpoint (averaging of incident field strength), a “radiation pattern” viewpoint (plane-wave spectral approach) can be used to represent the effects of different types of antennas. For instance, electrically-small antennas generally have a wide beamwidth, while large antennas are more directional and have a smaller beamwidth. This will influence the weighting of the direct and reflected field rays from the EUT. The uncertainty associated with different types of antennas may be expressed by considering the radiation pattern (directivity) of the antenna. Large uncertainties may result in case the radiation pattern collapses, meaning the gain in the direction of the direct field ray from the EUT is much smaller than the gain in the direction of the reflected field ray contribution. A quantitative analysis of this “directivity” influence quantity is given in [26], where the CISPR tuned dipole is used as the reference for judging the differences due to application of different types of receive antennas. The impact of the type of receive antenna depends on the following parameters:

– type of EUT (vertical polarisation, due to directivity of receive antenna);
– frequency (higher frequencies yield higher directivity of receive antenna patterns);
– measurement distance (smaller incidence angle of the reflected field at larger measurement distances).

See Table E.3 and Table E.4 in Annex E for uncertainty values as a function of measurement distance.

j) Antenna factor height dependence

The actual antenna factor will vary as a function of height above the ground plane, due to the coupling of the antenna with its image. On average, the free-space antenna factor is the best choice to replace the height-dependent antenna factor. The antenna factor height variation depends on:

– polarisation (substantial effect for horizontal polarisation, mostly negligible for vertical polarisation);
– antenna type (LPDA, biconical, etc) ;
– frequency (less coupling of the antenna with its image at higher frequencies due to larger distance in terms of wavelengths).

In reference [28], background information and quantitative information is available about antenna factor variations (with respect to the free-space antenna factor) for different types of antennas and as a function of frequency.

k) Antenna factor frequency interpolation

An antenna calibration report generally provides antenna factor data at a number of discrete frequencies. Antenna factors at intermediate frequencies are then often derived by linear interpolation. The uncertainty associated with antenna factor interpolations depends on the initial number of frequency points provided in the calibration report. Commercially available receive antennas generally have a smooth variation of the antenna factor as a function of the frequency, and therefore the uncertainty due to antenna factor interpolation is small. The maximum of half of the differences between two successive values of the antenna factor can be used to estimate the antenna factor interpolation uncertainty, using a rectangular distribution. Many antennas, particularly hybrids, have sharp changes of antenna factor with frequency, where the uncertainty will be larger; use of smaller frequency steps in the antenna calibration will minimize this uncertainty.

l) Antenna phase centre variation

It is advantageous to use the phase centre of the receive antenna as the reference point to establish the measurement distance between the EUT and the receive antenna, because the phase centre is the point on the antenna where the free-space antenna factor is applicable.

NOTE In the transmit mode, the phase centre can be considered as the apparent point source from which radiation originates. In general, the phase centre of an antenna may vary as a function of the angle of incidence, but this effect is small for EMC measurements.

For dipole-type antennas, the phase centre of the antenna is located between the two elements at the feed point (or balun). The position of the phase centre of an LPDA antenna varies with frequency, and it is located near the dipole element that is active at a certain frequency. Consequently, the position of the phase centre varies with respect to the fixed reference point of the LPDA antenna, which is usually taken to be midway between the elements that are resonant at the ends of the operating frequency range. Because the antenna reference point is at a fixed measurement distance from the EUT, the actual measurement distance may vary as a function of frequency. This distance variation effect (uncertainty) is largest at the ends of the operating frequency range, and is larger for shorter measurement distances. The uncertainty can be neglected for antennas, where the phase centre coincides with the reference point, e.g. tuned dipoles and biconical antennas.

Table E.3 and Table E.4 in Annex E include phase centre variation uncertainty values as a function of measurement distance. See also references [29], [21] for other information about phase centre considerations of LPDA antennas.

m) Antenna unbalance

The effect of an unbalanced antenna, i.e. when the balun has poor differential-to-common-mode conversion properties, is most evident in the low frequency range (<200 MHz) and when the measurement cable is oriented in parallel with the antenna elements. The pass/fail criterion for the unbalance of an antenna, i.e. response < 1 dB (see 4.4.2 of CISPR 16-1-4), provides an estimate for the resulting uncertainty (rectangular probability distribution).

n) Cross-polarisation performance

The cross-polarisation performance of an antenna indicates how the antenna responds to a cross-polarised incident plane wave, relative to a co-polarised incident plane wave. When an antenna is placed in a plane-polarized electromagnetic field, the terminal voltage when the antenna and field are cross-polarized shall be at least 20 dB below the terminal voltage when they are co-polarized (see CISPR 16-1-4, subclause 4.4.3). The cross-polarisation performance of dipole-type antennas (including biconical antennas) is generally negligible. LPDA antennas generally have a non-negligible cross-polar response. An LPDA illuminated by equal field strengths in horizontal and vertical polarisation (i.e. a field at 45°) will be measuring the co-polar field strength with an error of 0.9 dB if the cross-polar rejection of the LPDA is 20 dB [21]. The latter value may be used as an uncertainty estimate (rectangular probability distribution) in the frequency range where LPDAs are used (200 MHz to 1 000 MHz). The cross-polarisation induced uncertainty is relatively independent of measurement distance. In addition, at an OATS/SAC, the receive antenna may respond to longitudinal-polarised fields emitted by an EUT (see [30], [31], [32]); the contribution from this longitudinal component depends also on the measurement distance and the site performance. If the longitudinal cross-polarisation rejection for a given combination of receive antenna and test site is poor (susceptible to receive longitudinal field components), then the effect shall be accounted for in the uncertainty estimates. References [30], [31], [32] do not provide quantitative information on the uncertainties involved in responses to longitudinal-polarised field components. Future enhancements of the SAC/OATS measurement method should take this influence quantity into account.

o) Cable loss uncertainty

The uncertainty of the cable loss directly affects the uncertainty of the measurement result [see Equation (8-1)]. An estimate for the uncertainty of the loss of the measuring cable between antenna and receiver can be obtained from the cable calibration report (expanded uncertainty and normal distribution) or from manufacturer's data (specified tolerance and rectangular distribution). The level of cable-loss uncertainty is generally low, except when long cables are used on an OATS with large temperature variations (see also temperature effects discussion in 8.2.3.4).

p) Mismatch

This influence quantity is covered in 8.2.3.5 0; see also [25].

q) Measurement system repeatability

The measurement system repeatability can be evaluated from the standard deviation of a series of repeated measurements using a stable reference radiator. The measurement conditions for determining the measurement system repeatability should be considered carefully to avoid double counting of uncertainties in the uncertainty estimate. It should include typical variations caused by the measurement system that will occur in normal testing. The purpose of the measurement-system repeatability is to account for unpredictable (random) variations of influence quantities that have not been identified. Therefore repeatability measurements should not include rotation of the EUT (reference radiator in this case) and the receiving antenna should be fixed in height because those influence quantities have been addressed separately. Environment-related uncertainties may be identified as well by performing a measurement system repeatability check. However, these uncertainties may have already been included in the uncertainty estimate (see 8.2.3.4). Note that the uncertainty contribution from the reference radiator shall be very small. This may be verified from specifications or from direct measurement of the RF-output of the reference radiator.

8.2.4 Application of the uncertainty estimate

In general, knowledge of the expanded uncertainty of the SAC/OATS-based radiated emission measurement method serves two purposes: estimation of the measurement instrumentation uncertainty, and/or the standards compliance uncertainty.

8.2.4.1 Measurement instrumentation uncertainty (MIU) considerations

The MIU can be calculated for accreditation purposes of a test laboratory. For this purpose it is sufficient to consider the uncertainties induced by the test laboratory only, i.e. the uncertainties related to the measurement instrumentation, the environment, and the measurement procedure. The resulting MIU can be used to compare with the specified MIU value stated in CISPR 16-4-2, i.e. U_{CISPR} = 5,2 dB. If the MIU exceeds this U_{CISPR} value, the exceeding amount shall be accounted for in the pass/fail decision, as described in 4.1 of CISPR 16-4-2.

8.2.4.2 Standards compliance uncertainty (SCU) considerations

The SCU can be estimated for the measurement method in combination with a typical type of product. This value of the SCU can be used for assessment of risk of non-compliance against a certain radiated emissions limit. In cases of measurement correlation discussions between two test laboratories where the "same" measurement was performed using the "same" EUT, the uncertainties induced by the EUT must be included as well in the uncertainty estimate. In market surveillance situations, in principle the SCU should be considered by all of the involved parties (manufacturer and the authority), because the SCU is a relevant figure of merit for the reproducibility of the measurement method. However, an estimation of the SCU applicable for any type of EUT may be difficult in practice. Therefore, some other approach should be used for market surveillance applications.[2)]

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2) A new approach is under consideration in the CISPR A maintenance project initiated by CISPR/A/702/MCR (September 2006), on Treatment of uncertainties in compliance criteria (CISPR 16-4-1, Ed.2).

8.2.5 Typical examples of the uncertainty estimate

Table E.1 and Table E.2 in Annex E provide a typical uncertainty estimate for a SAC-based radiated emission measurement of a table-top EUT at a measurement distance of 3 m. Two tables are provided corresponding to the 30 MHz to 200 MHz and 200 MHz to 1 000 MHz frequency ranges. Two additional tables, Table E.3 and Table E.4, are provided which include uncertainty data for some influence quantities for the radiated emission measurement method at measurement distances of 3 m, 10 m, or 30 m. The uncertainty estimates are calculated in accordance with the procedure defined in Clause 4.

For the estimates presented in Annex E, most of the contributions are Type B evaluations, and use data from calibration certificates, instrumentation manuals, manufacturer's specifications, previous measurements, or from models or generic knowledge about the measurement method. The probability distributions and uncertainty values for the various uncertainty sources/influence quantities that are given in Annex E are derived from various sources of information, as discussed in 8.2.3.

Unfortunately, a model is not always available for the relationship between the measurand and the various influence quantities. In this case, only an assumption can be made that the measurand is a function of the influence quantities summarized in Table 8-1. Most standard uncertainty values for each influence quantity must be derived using Type B evaluation methods. Furthermore, it is assumed that all sensitivity coefficients are equal to one. However, in absence of a realistic model, actual values for the sensitivity coefficients are usually unknown.

For example, for measurements done at other than 10 m, the assumption used for the effects of the measurement distance on the field strength level is not correct. The maximum field strength at an alternative measurement distance does not vary linearly with distance, due to the presence of the ground plane and the field maximisation process. At close measurement distances and low frequencies, additional "non-linear" effects occur in the near-field region.

Table E.1 and Table E.2 each also provides results for both MIU and SCU calculations. For a 3 m measurement distance, the MIU is nearly 5,5 dB, whereas the SCU may be as large as approximately 15,5 dB.

8.2.6 Verification of the uncertainty estimate

Various round robin tests (RRTs), sometimes called interlaboratory comparison (ILC) measurements or site reproducibility programs (SRPs), have been performed previously for SAC/OATS-based radiated emission measurements, with results reported in various papers. The results of these RRTs are usful because they can provide insight into the actual uncertainties associated with SAC/OATS-based radiated emission measurements. Accordingly, RRT results can be used to support the validity of the uncertainty estimates shown in Annex E.

Table F.1 in Annex F summarizes relevant parameters and results from a number of RRTs. Figure F.1, Figure F.2, Figure F.3, and Figure F.4 in Annex F show sample results from some RRTs. The following conclusions can be drawn from these results.

a) Results of RRTs using a reference radiator show uncertainties (expanded, or 2σ) ranging from 3 dB to 6 dB. Reference radiators are generally stable and reproducible. RRTs using these simple types of EUTs fundamentally provide information about the MIU. This assumes a very simple EUT and a very detailed measurement procedure for the RRT. The range of uncertainty found is consistent with the results of the MIU estimates shown in Annex E.

b) Results of RRTs using a more complex and realistic EUT exhibit much larger uncertainties, i.e. up to 11 dB. This uncertainty estimate has also been confirmed by numerical modelling. The larger uncertainty is due to the intrinsic uncertainty of the EUT, i.e. a poor reproducibility of the set-up, combined with variable methods of terminating cables. RRTs using such realistic EUTs fundamentally provide information about the SCU. The range of uncertainty found is consistent with the results of the SCU values shown in Annex E.

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Add, after Annex D, the following new Annexes E and F:

Annex E
(informative)

Uncertainty estimates for the radiated emission measurement methods

This annex provides examples of typical uncertainty estimates for a radiated emission measurement method using a SAC at 3 m measurement distance and assuming a tabletop EUT. Table E.1 is for the frequency range 30 MHz to 200 MHz, and Table E.2 is for the frequency range 200 MHz to 1 000 MHz. Note that separate uncertainty estimates are not provided for horizontal and vertical polarisations, because actual radiated emission measurement results report a single figure for the maximum value of both horizontal and vertical polarisation at each frequency. Separate uncertainty figures for horizontal and vertical polarisations may provide further insights on the impact of specific uncertainty components, but are unnecessary for compliance test results.

Table E.1 – Uncertainty estimate for the radiated emission measurement method in the frequency range 30 MHz to 200 MHz at a measurement distance of 3 m

UNCERTAINTY SOURCES Influence quantities	Correction factor (dB)	Uncertainty value (+/- dB)	Probability distribution	Divisor	Standard uncertainty	Reference
EUT RELATED						
Size of EUT		0,0	rectangular	1,73	0,00	NOTE 1, SCU only
Type of disturbance		0,0	rectangular	1,73	0,00	NOTE 1, SCU only
Modes of operation		3,0	rectangular	1,73	1,73	SCU only
SETUP RELATED						
Layout of units and cables		6,0	rectangular	1,73	3,46	SCU only
Termination of cables		10,0	rectangular	1,73	5,77	SCU only
Measurement distance tolerance		0,4	rectangular	1,73	0,23	
EUT height above groundplane tolerance		0,2	rectangular	1,73	0,12	
MEASUREMENT PROCEDURE RELATED						
Nominal measurement distance	-10,5	4,0	rectangular	1,73	2,31	SCU only
Receiver settings		1,0	rectangular	1,73	0,58	
Height scanning step size		0,0	rectangular	1,73	0,00	
Start & stop position tolerance		0,0	rectangular	1,73	0,00	
Azimuth step size		0,1	rectangular	1,73	0,06	
ENVIRONMENT RELATED						
Temperature & humidity		0,1	rectangular	1,73	0,06	
Signal to ambient signal ratio		0,0	normal	2,00	0,00	
Mains voltage variation		0,2	rectangular	1,73	0,12	SCU only
MEASUREMENT INSTRUMENTATION RELATED						
Receiver accuracy		2,0	rectangular	1,73	1,16	
Mismatch at the receiver input		+0,9/-1,0	U-shaped	1,41	0,64	
Measuring system reading		0,1	rectangular	1,73	0,06	
Signal to noise ratio		0,5	normal	2,00	0,25	
NSA deviation		3,0	rectangular	1,73	1,73	
EUT positioning table		0,0	rectangular	1,73	0,00	
Free-space antenna factor uncertainty		1,5	normal	2,00	0,75	
Type of receive antenna (directivity)		0,0	rectangular	1,73	0,00	
Antenna factor height dependence		1,0	rectangular	1,73	0,58	
Antenna factor frequency interpolation		0,2	rectangular	1,73	0,12	
Antenna phase centre variation		0,0	rectangular	1,73	0,00	
Antenna unbalance		0,9	rectangular	1,73	0,52	
Cross polarization performance		0,0	rectangular	1,73	0,00	
Cable loss uncertainty		0,1	rectangular	1,73	0,06	
Measurement system repeatability		0,5	rectangular	1,73	0,29	
Combined Standard Uncertainty (SCU)					7,8	NOTE 2
Expanded Uncertainty (SCU)			normal	2,00	**15,5**	
Combined Standard Uncertainty (MIU)					2,5	NOTE 3
Expanded Uncertainty (MIU)			normal	2,00	**5,1**	

NOTE 1These influence quantities indirectly influence the uncertainty due to the set up of the EUT

NOTE 2 This Standard Compliance Uncertainty (SCU) includes all influence quantities

NOTE 3 This Measurement Instrumentation Uncertainty (MIU) includes all the influence quantities with the exception of the influence quantities indicated in the right column with 'SCU only'.

Table E.2 – Uncertainty estimate for the radiated emission measurement method in the frequency range 200 MHz to 1 000 MHz at a measurement distance of 3 m

UNCERTAINTY SOURCES Influence quantities	Correction factor (dB)	Uncertainty value (+/- dB)	Probability distribution	Divisor	Standard uncertainty	Reference
EUT RELATED						
Size of EUT		0,0	rectangular	1,73	0,00	NOTE 1, SCU only
Type of disturbance		0,0	rectangular	1,73	0,00	NOTE 1, SCU only
Modes of operation		3,0	rectangular	1,73	1,73	SCU only
SETUP RELATED						
Layout of units and cables		3,0	rectangular	1,73	1,73	SCU only
Termination of cables		3,0	rectangular	1,73	1,73	SCU only
Measurement distance tolerance		0,4	rectangular	1,73	0,23	
EUT height above groundplane tolerance		0,3	rectangular	1,73	0,17	
MEASUREMENT PROCEDURE RELATED						
Nominal measurement distance	-10,5	3,0	rectangular	1,73	1,73	SCU only
Receiver settings		1,0	rectangular	1,73	0,58	
Height scanning step size	0,1	0,0/-0,2	rectangular	1,73	0,06	
Start & stop position tolerance		0,5	rectangular	1,73	0,29	
Azimuth step size		0,3	rectangular	1,73	0,17	
ENVIRONMENT RELATED						
Temperature & humidity		0,1	rectangular	1,73	0,06	
Signal to ambient signal ratio		0,0	normal	2,00	0,00	
Mains voltage variation		0,2	rectangular	1,73	0,12	SCU only
MEASUREMENT INSTRUMENTATION RELATED						
Receiver accuracy		2,0	rectangular	1,73	1,16	
Mismatch at the receiver input		0,3	U-shaped	1,41	0,64	
Measuring system reading		0,1	rectangular	1,73	0,06	
Signal to noise ratio		0,5	normal	2,00	0,25	
NSA deviation		3,0	rectangular	1,73	1,73	
EUT positioning table		0,5	rectangular	1,73	0,29	
Free-space antenna factor uncertainty		1,5	normal	2,00	0,75	
Type of receive antenna (directivity)		1,5	rectangular	1,73	0,87	
Antenna factor height dependence		0,5	rectangular	1,73	0,29	
Antenna factor frequency interpolation		0,2	rectangular	1,73	0,12	
Antenna phase centre variation		1,0	rectangular	1,73	0,58	
Antenna unbalance		0,3	rectangular	1,73	0,17	
Cross polarization performance		0,9	rectangular	1,73	0,52	
Cable loss uncertainty		0,1	rectangular	1,73	0,06	
Measurement system repeatability		0,5	rectangular	1,73	0,29	
Combined Standard Uncertainty (SCU)					4,4	NOTE 2
Expanded Uncertainty (SCU)			normal	2,00	**8,9**	
Combined Standard Uncertainty (MIU)					2,8	NOTE 3
Expanded Uncertainty (MIU)			normal	2,00	**5,5**	

NOTE 1These influence quantities indirectly influence the uncertainty due to the set up of the EUT
NOTE 2 This Standard Compliance Uncertainty (SCU) includes all influence quantities
NOTE 3 This Measurement Instrumentation Uncertainty (MIU) includes all the influence quantities with the exception of the influence quantities indicated in the right column with 'SCU only'.

Table E.3 – Uncertainty data of some influence quantities for the radiated emission measurement method in the frequency range 30 MHz to 200 MHz at measurement distances of 3 m, 10 m, or 30 m

UNCERTAINTY SOURCES Influence quantities	Measurement distance (m)	Correction factor (dB)	Uncertainty value (+/- dB)	Probability distribution	Divisor	Standard uncertainty
Measurement distance tolerance	3		0,4	rectangular	1,73	0,23
	10		0,2	rectangular	1,73	0,10
	30		0,1	rectangular	1,73	0,05
EUT height above groundplane tolerance	3		0,2	rectangular	1,73	0,12
	10		0,1	rectangular	1,73	0,06
	30		0,1	rectangular	1,73	0,06
Nominal measurement distance	3	-10,5	4,0	rectangular	1,73	2,31
	10	0	N.A.			0,00
	30	10,5	4,0	rectangular	1,73	2,31
Height scanning step size	3		0,0	rectangular	1,73	0,00
	10		0,0	rectangular	1,73	0,00
	30		0,0	rectangular	1,73	0,00
Start & stop position tolerance	3		0,4	rectangular	1,73	0,23
	10		0,1	rectangular	1,73	0,06
	30		0,1	rectangular	1,73	0,06
Signal to ambient signal ratio	3		0,0	normal	2,00	0,00
	10		1,0	normal	2,00	0,50
	30		2,0	normal	2,00	1,00
Signal to noise ratio	3		0,5	normal	2,00	0,25
	10		1,0	normal	2,00	0,50
	30		2,0	normal	2,00	1,00
Type of receive antenna (directivity)	3		0,0	rectangular	1,73	0,00
	10		0,0	rectangular	1,73	0,00
	30		0,0	rectangular	1,73	0,00
Antenna phase centre variation	3		0,0	rectangular	1,73	0,00
	10		0,0	rectangular	1,73	0,00
	30		0,0	rectangular	1,73	0,00
Cross polarization performance	3		0,0	rectangular	1,73	0,00
	10		0,0	rectangular	1,73	0,00
	30		0,0	rectangular	1,73	0,00

Table E.4 – Uncertainty data of some influence quantities for the radiated emission measurement method in the frequency range 200 MHz to 1 000 MHz at measurement distances of 3 m, 10 m, or 30 m

UNCERTAINTY SOURCES Influence quantities	Measurement distance (m)	Correction factor (dB)	Uncertainty value (+/- dB)	Probability distribution	Divisor	Standard uncertainty
Measurement distance tolerance	3		0,4	rectangular	1,73	0,23
	10		0,2	rectangular	1,73	0,09
	30		0,1	rectangular	1,73	0,03
EUT height above groundplane tolerance	3		0,3	rectangular	1,73	0,17
	10		0,1	rectangular	1,73	0,06
	30		0,1	rectangular	1,73	0,06
Nominal measurement distance	3	-10,5	3,0	rectangular	1,73	1,73
	10	0	N.A.			0,00
	30	10,5	3,0	rectangular	1,73	1,73
Height scanning step size	3	0,1	0/-0,2	rectangular	1,73	0,06
	10	0,0	0,0	rectangular	1,73	0,00
	30	0,0	0,0	rectangular	1,73	0,00
Start & stop position tolerance	3		0,6	rectangular	1,73	0,35
	10		0,2	rectangular	1,73	0,09
	30		0,1	rectangular	1,73	0,06
Signal to ambient signal ratio	3		0,0	normal	2,00	0,00
	10		1,0	normal	2,00	0,50
	30		2,0	normal	2,00	1,00
Signal to noise ratio	3		0,5	normal	2,00	0,25
	10		1,0	normal	2,00	0,50
	30		2,0	normal	2,00	1,00
Type of receive antenna (directivity)	3		1,5	rectangular	1,73	0,87
	10		1,0	rectangular	1,73	0,58
	30		0,5	rectangular	1,73	0,29
Antenna phase centre variation	3		1,0	rectangular	1,73	0,58
	10		0,3	rectangular	1,73	0,17
	30		0,1	rectangular	1,73	0,06
Cross polarization performance	3		0,9	rectangular	1,73	0,52
	10		0,9	rectangular	1,73	0,52
	30		0,9	rectangular	1,73	0,52

Annex F
(informative)

Results of various round robin tests for SAC/OATS-based radiated emission measurements

F.1 Introduction

Various round robin tests (RRTs), also sometimes called interlaboratory comparison (ILC) measurements or site reproducibility programs (SRPs), have been performed previously for SAC/OATS-based radiated emission measurements, with results reported in various documents. Accomplishment of RRTs is a useful means to verify uncertainty estimates (see 4.5). Table F.1 summarizes relevant parameters and results from a number of RRTs. Figure F.1, Figure F.2, Figure F.3, Figure F.4, and Figure F.5 show some sample results from some of these RRTs. Figure F.1 shows the expanded uncertainties of emission measurement results for five different emulated EUTs, each with five different cable termination conditions [f2]. The results show that between 30 MHz and 200 MHz, application of different termination devices, such as common-mode absorbing device (CMADs), CDNs or LISNs, may cause a significant variation of results, i.e. 10 dB to 20 dB expanded uncertainty below 100 MHz. Figure F.2 shows Interlaboratory Comparison measurement results of twelve 10 m SACs. Figure F.3 gives ILC measurement results of radiated emission measurements of an emulated computer at eleven SAC/OATS sites at 3 m measurement distance [f3]. The EUT consist of 3 units and interfaces between the units and a power connection. An expanded uncertainty up to 11 dB can be observed which is mainly due to differences in set-up. Figure F.4 shows ILC measurement results of a reference radiator measured at 14 different SAC/OATS at 3 m measurement distance [f7], [f8]. In this case an overall expanded uncertainty of 3,3 dB is visible due to the good reproducibility of the EUT. Figure F.5 shows the conversion factor between 3 m and 10 m SAC/OATS-emission measurement results of a battery-fed table-top type of EUT as a function of frequency. In this figure the conversion factor is also compared with the free-space rule-of-thumb ratio of 10,5 dB [f7], [f8]. See also 8.2.6 for a discussion of the results.