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

Partie 4: Incertitudes de mesure CEM

Specification for radio disturbance and immunity measuring apparatus and methods –

Part 4: Uncertainty in EMC measurements

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SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

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FOREWORD

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International Standard CISPR 16-4 has been prepared by CISPR, subcommittee A: Radio-interference measurements and statistical methods.

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

FDIS	Report on voting
CISPR/A/355/FDIS	CISPR/A/377/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annex A is for information only.

The committee has decided that the contents of this publication will remain unchanged until 2004. At this date, the publication will be

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- withdrawn;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

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 4: Uncertainty in EMC measurements

1 Scope

This part of CISPR 16 is designated a basic standard, which specifies the manner in which measurement uncertainty is to be taken in to account in determining compliance with CISPR limits. The material is also relevant to any EMC test when interpretation of the results and conclusions reached will be impacted by the uncertainty of the instrumentation used during the testing. Annex A contains the background material used in providing the amount of measurement uncertainty found in generating the CISPR values shown in Clause 4 and hence provides valuable background material for those needing both initial and further information on measurement uncertainty and how to take into account individual uncertainties in the measurement chain. The annex however is not intended to be a tutorial of user manual or to be copied when making uncertainty calculations. For that, the references shown in the bibliography should be used.

Measurement instrumentation specifications are given in CISPR 16-1, while the methods of measurement are covered in CISPR 16-2. Further information on radio disturbance and other uncertainty considerations are given in CISPR 16-3.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CISPR 16-1:1999, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus*

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

CISPR 16-3, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 3: Reports and recommendations of CISPR*

3 Definitions and symbols

For the purpose of this part of CISPR 16, the following symbols apply.

NOTE General uncertainty terms and definitions used in uncertainty are contained in bibliography reference [2]. General definitions are contained in bibliography reference [1]. These definitions will not be repeated here.

3.1 General symbols

X_i	input quantity
x_i	estimate of X_i
$u(x_i)$	standard uncertainty of x_i
c_i	sensitivity coefficient
y	result of a measurement, (the estimate of the measurand), corrected for all recognised significant systematic effects
$u_c(y)$	(combined) standard uncertainty of y
k	coverage factor
U	expanded uncertainty of y

3.2 Measurands

V	Voltage, in dB(μV)
P	Disturbance power, in dB(pW)
E	Electric field strength, in dB(μV/m)

3.3 Input quantities

V_r	Receiver voltage reading, in dB(μV)
L_c	Attenuation of the connection between the receiver and the artificial mains network, absorbing clamp or antenna, in dB
L_{amn}	Voltage division factor of the AMN, in dB
L_{ac}	Insertion loss of the absorbing clamp, in dB
AF	Antenna factor, in dB(/m)
δV_{sw}	Correction for receiver sine wave voltage inaccuracy, in dB
δV_{pa}	Correction for imperfect receiver pulse amplitude response, in dB
δV_{pr}	Correction for imperfect receiver pulse repetition rate response, in dB
δV_{nf}	Correction for the effect of the receiver noise floor, in dB
δM	Correction for the error caused by mismatch, in dB
δMD	Correction for the error caused by mains disturbances, in dB
δZ	Correction for imperfect AMN impedance, in dB
δE	Correction for the effect of the environment, in dB
δAF_f	Correction for antenna factor interpolation error, in dB
δAF_h	Correction for the difference between the antenna factor variation with height, and the variation with height of the antenna factor of a reference dipole, in dB
δA_{dir}	Correction for antenna directivity, in dB
δA_{ph}	Correction for antenna phase centre location, in dB
δA_{cp}	Correction for antenna cross-polarisation response, in dB
δA_{bal}	Correction for antenna unbalance, in dB
δSA	Correction for imperfect site attenuation, in dB
δd	Correction for imperfect antenna distance, in dB
δh	Correction for imperfect table height above ground plane, in dB

4 Measurement instrumentation uncertainty

4.1 Overview

Measurement instrumentation uncertainty shall be taken into account when determining compliance or non-compliance with a disturbance limit.

The measurement instrumentation uncertainty for a test laboratory shall be evaluated for those measurements addressed in the following subclauses, taking into consideration each of the quantities listed there. The standard uncertainty $u(x_i)$ in decibels and the sensitivity coefficient c_i shall be evaluated for the estimate x_i of each quantity. The combined standard uncertainty $u_c(y)$ of the estimate y of the measurand shall be calculated as

$$u_c(y) = \sqrt{\sum_i c_i^2 \; u^2(x_i)}$$

The expanded measurement instrumentation uncertainty U_{lab} for a test laboratory shall be calculated as

$$U_{lab} = 2 \; u_c(y)$$

and shall be stated in the test report.

NOTE 1 The coverage factor $k = 2$ yields approximately a 95 % level of confidence for the near-normal distribution typical of most measurement results.

Compliance or non-compliance with a disturbance limit shall be determined in the following manner.

If U_{lab} is less than or equal to U_{cispr} in table 1, then:

– compliance is deemed to occur if no measured disturbance exceeds the disturbance limit;

– non-compliance is deemed to occur if any measured disturbance exceeds the disturbance limit.

NOTE U_{cispr} resembles a value of measurement uncertainty for a specific test, which was determined by considering uncertainties associated with the quantities listed in 4.2.

If U_{lab} is greater than U_{cispr} in table 1, then:

– compliance is deemed to occur if no measured disturbance, increased by (U_{lab} – U_{cispr}), exceeds the disturbance limit;

– non-compliance is deemed to occur if any measured disturbance, increased by (U_{lab} – U_{cispr}), exceeds the disturbance limit.

Table 1 – Values of U_{cispr}

Measurement		U_{cispr}
Conducted disturbance (mains port)	(9 kHz – 150 kHz)	4,0 dB
	(150 kHz – 30 MHz)	3,6 dB
Disturbance power	(30 MHz – 300 MHz)	4,5 dB
Radiated disturbance (electric field strength on an open area test site or alternative test site)	(30 MHz – 1 000 MHz)	5,2 dB
Other		Under consideration

NOTE 2 The values of U_{cispr} in Table 1 are based on the expanded uncertainties in Annex A, which were evaluated by considering uncertainties associated with the quantities listed below.

Nothing in this clause removes the requirement for measuring apparatus to comply with specifications in CISPR 16-1.

4.2 Quantities to be considered for conducted disturbance measurements at a mains port

- Receiver reading
- Attenuation of the connection between artificial mains network and receiver
- Artificial mains network voltage division factor
- Receiver sine-wave voltage accuracy
- Receiver pulse amplitude response
- Receiver pulse response variation with repetition frequency
- Receiver noise floor
- Mismatch effects between artificial mains network receiver port and receiver
- Artificial mains network impedance

4.3 Quantities to be considered for disturbance power measurements

- Receiver reading
- Attenuation of the connection between absorbing clamp and receiver
- Absorbing clamp insertion loss
- Receiver sine-wave voltage accuracy
- Receiver pulse amplitude response
- Receiver pulse response variation with repetition frequency
- Receiver noise floor
- Mismatch effects between absorbing clamp receiver port and receiver
- Effect of mains disturbances
- Effect of environment

4.4 Quantities to be considered for radiated disturbance measurements of electric field strength on an open area test site or alternative test site

- Receiver reading
- Attenuation of the connection between antenna and receiver
- Antenna factor
- Receiver sine-wave voltage accuracy
- Receiver pulse amplitude response
- Receiver pulse response variation with repetition frequency
- Receiver noise floor
- Mismatch effects between antenna port and receiver
- Antenna factor frequency interpolation
- Antenna factor variation with height
- Antenna directivity
- Antenna phase centre
- Antenna cross-polarisation response
- Antenna balance
- Test site
- Separation between equipment under test and measurement antenna
- Height of table supporting the equipment under test

Annex A
(informative)

Basis for U_{cispr} values in Table 1

A.1 General

The following clauses outline the approach used to determine U_{cispr} for the various measurements. The main uncertainty components for each measurement are identified and an estimate of their magnitude provided. All assumptions made are documented in Clause A.5 and referenced as notes in the actual uncertainty estimate.

Definitions of measurement uncertainty terms, and information on the evaluation and expression of the uncertainty of measurement are available in references [1] to [4] of the bibliography.

A.2 Conducted disturbance measurements at a mains port

The measurand V is calculated as:

$$V = V_r + L_c + L_{amn} + \delta V_{sw} + \delta V_{pa} + \delta V_{pr} + \delta V_{nf} + \delta M + \delta Z$$

Table A.1 – Conducted disturbances from 9 kHz to 150 kHz using a 50 Ω/50 µH + 5 Ω AMN

Input quantity	X_i	Uncertainty of x_i		$u(x_i)$	c_i	$c_i\,u(x_i)$
		dB	Probability distribution function	dB		dB
Receiver reading 1) a	V_r	±0,1	k = 1	0,10	1	0,10
Attenuation: AMN-receiver 2)	L_c	±0,1	k = 2	0,05	1	0,05
AMN voltage division factor 3)	L_{amn}	±0,2	k = 2	0,10	1	0,10
Receiver corrections:						
Sine wave voltage 4)	δV_{sw}	±1,0	k = 2	0,50	1	0,50
Pulse amplitude response 5)	δV_{pa}	±1,5	Rectangular	0,87	1	0,87
Pulse repetition rate response 5)	δV_{pr}	±1,5	Rectangular	0,87	1	0,87
Noise floor proximity 6)	δV_{nf}	±0,0		0,00	1	0,00
Mismatch: AMN-receiver 7)	δM	+0,7/–0,8	U-shaped	0,53	1	0,53
AMN impedance 8)	δZ	+3,1/–3,6	Triangular	1,37	1	1,37
a For numbered comments, see article A.5.						

Hence: $2\,u_c(V) = 3{,}97$ dB

Table A.2 – Conducted disturbances from 150 kHz to 30 MHz using a 50 Ω/50 μH AMN

Input quantity	X_i	Uncertainty of x_i dB	Probability distribution function	$u(x_i)$ dB	c_i	$c_i\,u(x_i)$ dB
Receiver reading [1)] [a]	V_r	±0,1	k = 1	0,10	1	0,10
Attenuation: AMN-receiver [2)]	L_c	±0,1	k = 2	0,05	1	0,05
AMN voltage division factor [3)]	L_{amn}	±0,2	k = 2	0,10	1	0,10
Receiver corrections:						
Sine wave voltage [4)]	δV_{sw}	±1,0	k = 2	0,50	1	0,50
Pulse amplitude response [5)]	δV_{pa}	±1,5	Rectangular	0,87	1	0,87
Pulse repetition rate response [5)]	δV_{pr}	±1,5	Rectangular	0,87	1	0,87
Noise floor proximity [6)]	δV_{nf}	±0,0		0,00	1	0,00
Mismatch: AMN-receiver [7)]	δM	+0,7/–0,8	U-shaped	0,53	1	0,53
AMN impedance [8)]	δZ	+2,6/–2,7	Triangular	1,08	1	1,08
[a] For numbered comments, see article A.5.						

Hence: $2\,u_c(V)$ = 3,60 dB

A.3 Disturbance power measurements

The measurand P is calculated as:

$$P = V_r + L_c + L_{ac} - 10\log_{10}(50) + \delta V_{sw} + \delta V_{pa} + \delta V_{pr} + \delta V_{nf} + \delta M + \delta MD + \delta E$$

Table A.3 – Disturbance power from 30 MHz to 300 MHz

Input quantity	X_i	Uncertainty of x_i dB	Probability distribution function	$u(x_i)$ dB	c_i	$c_i\,u(x_i)$ dB
Receiver reading [1)] [a]	V_r	±0,1	k = 1	0,10	1	0,10
Attenuation: Absorbing clamp-receiver [2)]	L_c	±0,1	k = 2	0,05	1	0,05
Absorbing clamp insertion loss [9)]	L_{ac}	±3,0	k = 2	1,50	1	1,50
Receiver corrections:						
Sine wave voltage [4)]	δV_{sw}	±1,0	k = 2	0,50	1	0,50
Pulse amplitude response [5)]	δV_{pa}	±1,5	Rectangular	0,87	1	0,87
Pulse repetition rate response [5)]	δV_{pr}	±1,5	Rectangular	0,87	1	0,87
Noise floor proximity [6)]	δV_{nf}	±0,0		0,00	1	0,00
Mismatch: Absorbing clamp-receiver [7)]	δM	+0,7/–0,8	U-shaped	0,53	1	0,53
Effect of mains disturbances [10)]	δMD	±0,0		0,00	1	0,00
Effect of environment [11)]	δE	±0,8	k = 1	0,80	1	0,80
[a] For numbered comments, see article A.5.						

Hence: $2\,u_c(P)$ = 4,45 dB

A.4 Radiated disturbance measurements of electric field strength on an open area test site or alternative test site

The measurand E is calculated as:

$$E = V_r + L_c + AF + \delta V_{sw} + \delta V_{pa} + \delta V_{pr} + \delta V_{nf} + \delta M + \delta AF_f + \delta AF_h + \delta A_{dir} + \delta A_{ph} + \delta A_{cp} + \delta A_{bal} + \delta SA + \delta d + \delta h$$

Table A.4 – Horizontally polarised radiated disturbances from 30 MHz to 200 MHz using a biconical antenna at a distance of 3 m, 10 m, or 30 m

Input quantity		X_i	Uncertainty of x_i		$u(x_i)$	c_i	$c_i\,u(x_i)$
			dB	Probability distribution function	dB		dB
Receiver reading 1) a		V_r	±0,1	k = 1	0,10	1	0,10
Attenuation: antenna-receiver 2)		L_c	±0,1	k = 2	0,05	1	0,05
Biconical antenna factor 12)		AF	±2,0	k = 2	1,00	1	1,00
Receiver corrections:							
Sine wave voltage 4)		δV_{sw}	±1,0	k = 2	0,50	1	0,50
Pulse amplitude response 5)		δV_{pa}	±1,5	Rectangular	0,87	1	0,87
Pulse repetition rate response 5)		δV_{pr}	±1,5	Rectangular	0,87	1	0,87
Noise floor proximity 6)		δV_{nf}	±0,5	k = 2	0,25	1	0,25
Mismatch: antenna-receiver 7)		δM	+0,9/–1,0	U-shaped	0,67	1	0,67
Biconical antenna corrections:							
AF frequency interpolation 13)		δAF_f	±0,3	Rectangular	0,17	1	0,17
AF height deviations 14)		δAF_h	±0,5	Rectangular	0,29	1	0,29
Directivity difference 15)	at 3 m	δA_{dir}	±0,0		0,00	1	0,00
	or 10 m	δA_{dir}	±0,0		0,00	1	0,00
	or 30 m	δA_{dir}	±0,0		0,00	1	0,00
Phase centre location 16)	at 3 m	δA_{ph}	±0,0		0,00	1	0,00
	or 10 m	δA_{ph}	±0,0		0,00	1	0,00
	or 30 m	δA_{ph}	±0,0		0,00	1	0,00
Cross-polarisation 17)		δA_{cp}	±0,0		0,00	1	0,00
Balance 18)		δA_{bal}	±0,3	Rectangular	0,17	1	0,17
Site corrections:							
Site imperfections 19)		δSA	±4,0	Triangular	1,63	1	1,63
Separation distance 20)	at 3 m	δd	±0,3	Rectangular	0,17	1	0,17
	or 10 m	δd	±0,1	Rectangular	0,06	1	0,06
	or 30 m	δd	±0,0		0,00	1	0,00
Table height 21)	at 3 m	δh	±0,1	k = 2	0,05	1	0,05
	or 10 m	δh	±0,1	k = 2	0,05	1	0,05
	or 30 m	δh	±0,1	k = 2	0,05	1	0,05
a For numbered comments, see article A.5.							

Hence: $2\,u_c(E)$ = 4,95 dB at a separation of 3 m
4,94 dB at a separation of 10 m
4,94 dB at a separation of 30 m

Table A.5 – Vertically polarised radiated disturbances from 30 MHz to 200 MHz using a biconical antenna at a distance of 3 m, 10 m, or 30 m

Input quantity		X_i	Uncertainty of x_i		$u(x_i)$	c_i	$c_i\,u(x_i)$
			dB	Probability distribution function	dB		dB
Receiver reading 1) a		V_r	±0,1	k = 1	0,10	1	0,10
Attenuation: antenna-receiver 2)		L_c	±0,1	k = 2	0,05	1	0,05
Biconical antenna factor 12)		AF	±2,0	k = 2	1,00	1	1,00
Receiver corrections:							
Sine wave voltage 4)		δV_{sw}	±1,0	k = 2	0,50	1	0,50
Pulse amplitude response 5)		δV_{pa}	±1,5	Rectangular	0,87	1	0,87
Pulse repetition rate response 5)		δV_{pr}	±1,5	Rectangular	0,87	1	0,87
Noise floor proximity 6)		δV_{nf}	±0,5	k = 2	0,25	1	0,25
Mismatch: antenna-receiver 7)		δM	+0,9/–1,0	U-shaped	0,67	1	0,67
Biconical antenna corrections:							
AF frequency interpolation 13)		δAF_f	±0,3	Rectangular	0,17	1	0,17
AF height deviations 14)		δAF_h	±0,3	Rectangular	0,17	1	0,17
Directivity difference 15)	at 3 m	δA_{dir}	+1,0/–0,0	Rectangular	0,29	1	0,29
	or 10 m	δA_{dir}	+1,0/–0,0	Rectangular	0,29	1	0,29
	or 30 m	δA_{dir}	+0,5/–0,0	Rectangular	0,14	1	0,14
Phase centre location 16)	at 3 m	δA_{ph}	±0,0		0,00	1	0,00
	or 10 m	δA_{ph}	±0,0		0,00	1	0,00
	or 30 m	δA_{ph}	±0,0		0,00	1	0,00
Cross-polarisation 17)		δA_{cp}	±0,0		0,00	1	0,00
Balance 18)		δA_{bal}	±0,9	Rectangular	0,52	1	0,52
Site corrections:							
Site imperfections 19)		δSA	±4,0	Triangular	1,63	1	1,63
Separation distance 20)	at 3 m	δd	±0,3	Rectangular	0,17	1	0,17
	or 10 m	δd	±0,1	Rectangular	0,06	1	0,06
	or 30 m	δd	±0,0		0,00	1	0,00
Table height 21)	at 3 m	δh	±0,1	k = 2	0,05	1	0,05
	or 10 m	δh	±0,1	k = 2	0,05	1	0,05
	or 30 m	δh	±0,1	k = 2	0,05	1	0,05

[a] For numbered comments, see article A.5.

Hence: $2\,u_c(E)$ = 5,06 dB at a separation of 3 m
5,04 dB at a separation of 10 m
5,02 dB at a separation of 30 m

Table A.6 – Horizontally polarised radiated disturbances from 200 MHz to 1 GHz using a log-periodic antenna at a distance of 3 m, 10 m, or 30 m

Input quantity		X_i	Uncertainty of x_i dB	Probability distribution function	$u(x_i)$ dB	c_i	$c_i\, u(x_i)$ dB
Receiver reading [1) a]		V_r	±0,1	k = 1	0,10	1	0,10
Attenuation: antenna-receiver [2)]		L_c	±0,1	k = 2	0,05	1	0,05
Log-periodic antenna factor [12)]		AF	±2,0	k = 2	1,00	1	1,00
Receiver corrections:							
Sine wave voltage [4)]		δV_{sw}	±1,0	k = 2	0,50	1	0,50
Pulse amplitude response [5)]		δV_{pa}	±1,5	Rectangular	0,87	1	0,87
Pulse repetition rate response [5)]		δV_{pr}	±1,5	Rectangular	0,87	1	0,87
Noise floor proximity [6)]		δV_{nf}	±0,5	k=2	0,25	1	0,25
Mismatch: antenna-receiver [7)]		δM	+0,9/–1,0	U-shaped	0,67	1	0,67
Log-periodic antenna corrections:							
AF frequency interpolation [13)]		δAF_f	±0,3	Rectangular	0,17	1	0,17
AF height deviations [14)]		δAF_h	±0,3	Rectangular	0,17	1	0,17
Directivity difference [15)]	at 3 m	δA_{dir}	+1,0/–0,0	Rectangular	0,29	1	0,29
	or 10 m	δA_{dir}	+1,0/–0,0	Rectangular	0,29	1	0,29
	or 30 m	δA_{dir}	+0,5/–0,0	Rectangular	0,14	1	0,14
Phase centre location [16)]	at 3 m	δA_{ph}	±1,0	Rectangular	0,58	1	0,58
	or 10 m	δA_{ph}	±0,3	Rectangular	0,17	1	0,17
	or 30 m	δA_{ph}	±0,1	Rectangular	0,06	1	0,06
Cross-polarisation [17)]		δA_{cp}	±0,9	Rectangular	0,52	1	0,52
Balance [18)]		δA_{bal}	±0,0		0,00	1	0,00
Site corrections:							
Site imperfections [19)]		δSA	±4,0	Triangular	1,63	1	1,63
Separation distance [20)]	at 3 m	δd	±0,3	Rectangular	0,17	1	0,17
	or 10 m	δd	±0,1	Rectangular	0,06	1	0,06
	or 30 m	δd	±0,0		0,00	1	0,00
Table height [21)]	at 3 m	δh	±0,1	k = 2	0,05	1	0,05
	or 10 m	δh	±0,1	k = 2	0,05	1	0,05
	or 30 m	δh	±0,1	k = 2	0,05	1	0,05

[a] For numbered comments, see article A.5.

Hence: $2\, u_c(E)$ = 5,19 dB at a separation of 3 m
5,06 dB at a separation of 10 m
5,02 dB at a separation of 30 m

Table A.7 – Vertically polarised radiated disturbances from 200 MHz to 1 GHz using a log-periodic antenna at a distance of 3 m, 10 m, or 30 m

Input quantity		X_i	Uncertainty of x_i dB	Probability distribution function	$u(x_i)$ dB	c_i	$c_i\,u(x_i)$ dB
Receiver reading [1) a]		V_r	±0,1	k = 1	0,10	1	0,10
Attenuation: antenna-receiver [2)]		L_c	±0,1	k = 2	0,05	1	0,05
Log-periodic antenna factor [12)]		AF	±2,0	k = 2	1,00	1	1,00
Receiver corrections:							
Sine wave voltage [4)]		δV_{sw}	±1,0	k = 2	0,50	1	0,50
Pulse amplitude response [5)]		δV_{pa}	±1,5	Rectangular	0,87	1	0,87
Pulse repetition rate response [5)]		δV_{pr}	±1,5	Rectangular	0,87	1	0,87
Noise floor proximity [6)]		δV_{nf}	±05	k = 2	0,25	1	0,25
Mismatch: antenna-receiver [7)]		δM	+0,9/–1,0	U-shaped	0,67	1	0,67
Log-periodic antenna corrections:							
AF frequency interpolation [13)]		δAF_f	±0,3	Rectangular	0,17	1	0,17
AF height deviations [14)]		δAF_h	±0,1	Rectangular	0,06	1	0,06
Directivity difference [15)]	at 3 m	δA_{dir}	+1,0/–0,0	Rectangular	0,29	1	0,29
	or 10 m	δA_{dir}	+1,0/–0,0	Rectangular	0,29	1	0,29
	or 30 m	δA_{dir}	+0,5/–0,0	Rectangular	0,14	1	0,14
Phase centre location [16)]	at 3 m	δA_{ph}	±1,0	Rectangular	0,58	1	0,58
	or 10 m	δA_{ph}	±0,3	Rectangular	0,17	1	0,17
	or 30 m	δA_{ph}	±0,1	Rectangular	0,06	1	0,06
Cross-polarisation [17)]		δA_{cp}	±0,9	Rectangular	0,52	1	0,52
Balance [18)]		δA_{bal}	±0,0		0,00	1	0,00
Site corrections:							
Site imperfections [19)]		δSA	±4,0	Triangular	1,63	1	1,63
Separation distance [20)]	at 3 m	δd	±0,3	Rectangular	0,17	1	0,17
	or 10 m	δd	±0,1	Rectangular	0,06	1	0,06
	or 30 m	δd	±0,0		0,00	1	0,00
Table height [21)]	at 3 m	δh	±0,1	k = 2	0,05	1	0,05
	or 10 m	δh	±0,1	k = 2	0,05	1	0,05
	or 30 m	δh	±0,1	k = 2	0,05	1	0,05

[a] For numbered comments, see article A.5.

Hence: $2\,u_c(E)$ = 5,18 dB at a separation of 3 m
5,05 dB at a separation of 10 m
5,01 dB at a separation of 30 m

A.5 Comments on the estimates of input quantities

The uncertainty associated with an estimate x_i of an input quantity in the above tables is the largest uncertainty considered likely within the frequency range covered by the table, provided that it is consistent with the measuring apparatus specification tolerances in CISPR 16-1. Superscripts to input quantities refer to the numbered comments below. The expanded uncertainties provide the values of U_{cispr} in Table 1.

The standard uncertainty $u(x_i)$ is calculated by dividing the value of the uncertainty associated with x_i by a factor which depends on the probability distribution of that uncertainty and on the level of confidence associated with the value. For a U-shaped, rectangular or triangular probability distribution, where X_i is estimated to lie between $(x_i - a^-)$ and $(x_i + a^+)$ with a level of confidence of 100 %, $u(x_i)$ is taken as $a/\sqrt{2}$, $a/\sqrt{3}$, or $a/\sqrt{6}$ respectively, where $a = (a^+ + a^-)/2$ is the half-width of the probability distribution. For a normal probability distribution, the divisor is 2 if the value of the uncertainty associated with x_i has a level of confidence of 95 % (the value is twice the experimental standard deviation), or 1 if the value of the uncertainty associated with x_i has a level of confidence of 68 % (the value is the experimental standard deviation).

A correction is compensation for a systematic error. A correction may be known from calibration reports or from calculation. A correction which is not known, but is considered to be equally likely to be positive or negative, is taken to be zero. All corrections are assumed to have been applied, in accordance with the model. Every correction has an associated uncertainty.

The assumptions which led to the values in the above tables may not be appropriate for a particular test-laboratory. When a test-laboratory evaluates its expanded measurement instrumentation uncertainty U_{lab}, it must consider the information available on its particular measuring system, including equipment characteristics, the quality and currency of calibration data, the known or likely probability distributions, and measurement procedures. A test-laboratory may find it advantageous to evaluate its uncertainties over subdivisions of the frequency range, particularly if a dominant uncertainty varies significantly over that range.

A note following a comment is intended to provide some guidance to test-laboratories confronted with data or situations different to those assumed here.

1) Receiver readings will vary for reasons which include measuring system instability, receiver noise, and meter scale interpolation errors.

   The estimate of V_r is the mean of many readings, with a standard uncertainty given by the experimental standard deviation of the mean ($k = 1$).

2) An estimate of the attenuation L_c of the connection between the receiver and the AMN, absorbing clamp, or antenna, was assumed to be available from a calibration report, along with an expanded uncertainty and a coverage factor.

   NOTE If the estimate of attenuation L_c is obtained from manufacturer's data for a cable or attenuator, a rectangular probability distribution having a half-width equal to the manufacturer's specified tolerance on the attenuation may be assumed. If the connection is a cable and attenuator in tandem, with manufacturer's data available on each, L_c has two components, each with its own rectangular probability distribution.

3) An estimate of the AMN voltage division factor L_{amn} was assumed to be available from a calibration report, along with an expanded uncertainty and a coverage factor.

4) An estimate of the correction δV_{sw} for receiver sine-wave voltage accuracy was assumed to be available from a calibration report, along with an expanded uncertainty and a coverage factor.

NOTE If a calibration report states only that the receiver sine-wave voltage accuracy is within the CISPR 16-1 tolerance (±2 dB), then the estimate of the correction δV_{sw} should be taken as zero with a rectangular probability distribution having a half-width of 2 dB.

5) In general it is impractical to correct for imperfect receiver pulse response characteristics.

A verification report stating that the receiver pulse amplitude response complies with the CISPR 16-1 tolerance of ±1,5 dB for peak, quasi-peak, average, or RMS detection was assumed to be available. The correction δV_{pa} was estimated to be zero with a rectangular probability distribution having a half-width of 1,5 dB.

The CISPR 16-1 tolerance for pulse repetition rate response varies with repetition rate and detector type. A verification report stating that the receiver pulse repetition rate responses comply with the CISPR 16-1 tolerances was assumed to be available. The correction δV_{pr} was estimated to be zero with a rectangular probability distribution having a half-width of 1,5 dB, a value considered to be representative of the various CISPR 16-1 tolerances.

NOTE If the pulse amplitude response or the pulse repetition rate response is verified to be within $\pm\alpha$ dB of the CISPR specification ($\alpha \leq 1{,}5$), the correction for that response may be estimated to be zero with a rectangular probability distribution having a half-width of α dB.

If a disturbance produces a continuous wave signal at the detector, pulse response corrections need not be considered.

6) The noise floor of a CISPR receiver is usually sufficiently far below the disturbance voltage limit or the disturbance power limit that its effect is negligible on measurement results near those limits. However for radiated disturbances, the proximity of the receiver noise floor may influence measurement results near the radiated disturbance limit.

For radiated disturbance measurement, the correction δV_{nf} was estimated to be zero with an expanded uncertainty of 0,5 dB and a coverage factor of 2.

7) In general, the receiver port of an AMN, absorbing clamp or antenna will be connected to port 1 of a two-port network whose port 2 is terminated by a receiver of reflection coefficient Γ_r. The two-port network, which might be a cable, attenuator, attenuator and cable in tandem, or some other combination of components, can be represented by its S-parameters. The mismatch correction is then

$$\delta M = 20 \log_{10}\left[(1-\Gamma_e S_{11})(1-\Gamma_r S_{22}) - S_{21}^2 \Gamma_e \Gamma_r\right]$$

where Γ_e is the reflection coefficient seen looking into the receiver port of the AMN or absorbing clamp with the EUT connected, or looking into the output port of the antenna when it is set up for disturbance measurement. All parameters are with respect to 50 Ω.

When only the magnitudes, or extremes of magnitudes, of the parameters are known, it is not possible to calculate δM, but its extreme values $\delta M^{\pm}$ are not greater than

$$\delta M^{\pm} = 20 \log_{10}\left[1 \pm \left(|\Gamma_e||S_{11}| + |\Gamma_r||S_{22}| + |\Gamma_e||\Gamma_r||S_{11}||S_{22}| + |\Gamma_e||\Gamma_r||S_{21}|^2\right)\right]$$

The probability distribution of δM is approximately U-shaped, with width not greater than $(\delta M^{+} - \delta M^{-})$ and standard deviation not greater than the half-width divided by $\sqrt{2}$.

For disturbance voltage and disturbance power measurements, Γ_e is a function of the EUT impedance which is, in general, unknown and unbounded.

Worst-case reflection coefficient magnitudes of $|\Gamma_e| = 1$ were assumed. It was also assumed that the connection to the receiver was a well-matched cable ($|S_{11}|<<1$, $|S_{22}|<<1$) of negligible attenuation ($|S_{21}|\approx 1$), and that the receiver RF attenuation was 10 dB or more, for which the CISPR 16-1 tolerance of VSWR (voltage standing wave ratio) ≤1,2:1 implies $|\Gamma_r| \le 0{,}09$.

For radiated disturbance measurements, an antenna specification of VSWR ≤ 2,0:1 was assumed, implying $|\Gamma_e| \le 0{,}33$. It was also assumed that the connection to the receiver was a well-matched cable ($|S_{11}|<<1$, $|S_{22}|<<1$) of negligible attenuation ($|S_{21}|\approx 1$), and that the receiver RF attenuation was 0 dB, for which the CISPR 16-1 tolerance of VSWR ≤ 2,0:1 implies $|\Gamma_r| \le 0{,}33$.

The estimate of the correction δM was zero with a U-shaped probability distribution having width equal to the difference ($\delta M^+ - \delta M^-$).

NOTE The expressions for δM and $\delta M^{\pm}$ show that mismatch error can be reduced by increasing the attenuation of the well-matched two-port network preceding the receiver. The penalty is a reduction in measurement sensitivity.

For some antennas at some frequencies, the VSWR may be much greater than 2,0:1.

Precautions may be needed to ensure that the impedance seen by the receiver complies with the CISPR 16-1 specification of VSWR ≤ 2,0:1 when a complex antenna is used.

If an AMN or absorbing clamp is calibrated to the output port of an attenuator connected permanently to it, the effect of the EUT impedance on the mismatch error will be reduced as the value of the attenuation is increased.

8) The impedance tolerance in CISPR 16-1 for a 50 Ω/50 µH + 5 Ω AMN or a 50 Ω/50 µH AMN requires the impedance magnitude to be within 20 % of the magnitude of the nominal impedance when the receiver port is terminated in 50 Ω. The absence of any CISPR 16-1 restriction on the impedance phase gives rise to an unlimited measurement uncertainty on the voltage developed across the AMN by an EUT.

   It was assumed that the impedance presented by the AMN EUT port when the receiver port was terminated in 50 Ω lay within a circle centred on the nominal impedance on the complex-impedance plane, that circle having a radius of 20 % of the nominal impedance magnitude. This placed a tolerance on the impedance phase commensurate with that on the impedance magnitude. The estimate of the correction δZ was zero with a probability distribution bounded by the extremes from all combinations of the constrained AMN impedance and unconstrained EUT impedance over the defined frequency range. A triangular probability distribution was assumed because there is only a small chance of encountering the particular combinations of frequency, AMN impedance and EUT impedance needed to produce those extremes.

9) An estimate of absorbing clamp insertion loss L_{ac} was assumed to be available from a calibration report, along with an expanded uncertainty and a coverage factor.

10) Mains disturbances which are inadequately isolated from the absorbing clamp current transformer may affect the receiver reading. Fixing ferrite absorber along the mains cord near the mains supply, or using an AMN to provide a filtered mains supply, may be necessary to reduce the effect of mains disturbances.

   It was assumed that any mains disturbances were negligible, or their effect had been reduced to a negligible amount by appropriate suppression measures. The estimate of the correction δMD was zero with an uncertainty of zero.

   NOTE If mains disturbances are not negligible and their effect on the receiver reading has not been reduced adequately by appropriate suppression measures, a non-zero estimate of the correction and its uncertainty should be included.

11) Measurements of disturbance power using an absorbing clamp are sensitive to the surrounding environment, including the nature and proximity of room surfaces. It is difficult to determine the correction δE needed to account for the difference between the environment in which the absorbing clamp is calibrated and that in which it is used.

The estimate of the correction δE was zero with a standard deviation derived from values obtained when a common artefact was measured in different environments.

NOTE If an absorbing clamp is calibrated and used in the same environment, the correction δE need not be considered.

12) An estimate of the free space antenna factor AF was assumed to be available from a calibration report, along with an expanded uncertainty and a coverage factor.

13) When an antenna factor is calculated by interpolation between frequencies at which calibration data are available, the uncertainty associated with that antenna factor depends on the frequency interval between calibration points and the variability of antenna factor with frequency. Plotting calibrated antenna factor against frequency helps visualise the situation.

The estimate of the correction δAF_f for antenna factor interpolation error was zero, with a rectangular probability distribution having a half-width of 0,3 dB.

NOTE At any frequency for which a calibrated antenna factor is available, the correction δAF_f need not be considered.

14) The height dependence of antenna factor for a complex antenna will differ from that for a dipole antenna, which is the CISPR 16-1 designated reference antenna from 30 MHz to 300 MHz.

The estimate of the correction δAF_h was zero with a rectangular probability distribution having a half-width evaluated from the behaviour of biconical and log-periodic antenna factor with height.

NOTE If a dipole is the measuring antenna, or at frequencies above 300 MHz, the correction δAF_h need not be considered.

15) CISPR 16-1 requires the responses of a complex antenna in the direction of the direct ray and in the direction of the ground-reflected ray to be within 1 dB of the maximum response. To meet this requirement, the boresight of the complex antenna may need to be tilted downwards, particularly at separations of less than 10 m. The correction δA_{dir} for the effect of directivity is 0 dB for an antenna having a uniform pattern in the vertical plane, and between 0 dB and +1 dB for an antenna having a non-uniform pattern in the vertical plane.

A horizontally-polarised biconical antenna was assumed to have a uniform pattern in the vertical plane. A vertically polarised biconical antenna, and a horizontally or vertically polarised log-periodic antenna were assumed to require a correction δA_{dir} of up to +1 dB at separations of 3 m and 10 m, but not more than +0,5 dB at a separation of 30 m.

The estimate of the correction δA_{dir} was zero with a rectangular probability distribution having the appropriate width.

NOTE A non-zero estimate of δA_{dir} with reduced uncertainty could be evaluated from the known pattern of the measuring antenna, and applied as a function of frequency and separation. If a dipole is the measuring antenna, CISPR 16-1 imposes no explicit requirements on the responses in the directions of the direct ray and ground-reflected ray, and the correction δA_{dir} need not be considered.

16) The correction δA_{ph} for phase centre location is negligible for a biconical antenna, but the change in phase-centre location with frequency for a log-periodic antenna causes a deviation from the required separation.

For a log-periodic antenna, the estimate of the correction δA_{ph} was zero with a rectangular probability distribution having a half-width evaluated by considering the effect of an error of ±0,35 m in the separation and assuming that field strength is inversely proportional to separation.

NOTE If a dipole is the measuring antenna, the correction δA_{ph} is negligible.

17) The cross-polarisation response of a biconical antenna was considered to be negligible. The estimate of the correction δA_{cp} for cross-polarisation response of a log-periodic antenna was zero with a rectangular probability distribution having a half-width of 0,9 dB, corresponding to the CISPR 16-1 cross-polarisation response tolerance of –20 dB.

NOTE If a dipole is used as the measuring antenna the correction δA_{cp} is negligible.

18) The effect of an unbalanced antenna is greatest when the input coaxial cable is aligned parallel to the antenna elements. The estimate of the correction δA_{bal} for antenna unbalance was zero with a rectangular probability distribution having a half-width evaluated from the performance of commercially available antennas.

19) The magnitude D_{max} of the maximum difference between theoretical site attenuation on the one hand, and measured site attenuation increased by the site attenuation measurement uncertainty on the other, provides an indication of the effect that site imperfection may have on a disturbance measurement. The CISPR 16-1 tolerance for this difference is ±4 dB. However, the measurement uncertainty associated with the CISPR 16-1 site attenuation measurement method is usually large, and dominated by the two antenna factor uncertainties. Therefore a site which meets the 4 dB tolerance is unlikely to have imperfections sufficient to cause errors of 4 dB in disturbance measurements. In recognition of this, a triangular probability distribution is assumed for the correction δSA.

The estimate of the correction δSA was zero with a triangular probability distribution having a half-width of 4 dB.

Future improvement of the site validation methods in CISPR 16-1 will reduce the tolerance specification.

NOTE If D_{max} is less than 4 dB, the estimate of the correction δSA may be taken as zero with a triangular probability distribution of half-width D_{max}.

20) The error in separation arises from the errors in determining the perimeter of the EUT, distance measurement, and antenna mast tilt. The estimate of the correction δd for separation error was zero with a rectangular probability distribution having a half-width evaluated from assuming a maximum separation error of ±0,1 m, and that field strength is inversely proportional to separation over that distance margin.

21) The error caused by the equipment under test being placed on a table of other than nominal height of 0,8 m. The correction δh to be applied to the maximum measured field strength to correct for a table height which deviates by up to ±0,01 m from nominal was estimated to be zero, with a normal probability distribution having an expanded uncertainty of 0,1 dB at the 95 % level of confidence.

Bibliography

[1] *International Vocabulary of Basic and General Terms in Metrology,* ISO, 1993, ISBN 92-67-01075-1.

[2] ISO/IEC GUIDE EXPRES:1995, *Guide to the Expression of Uncertainty in Measurement.*

[3] TAYLOR, BN. and KUYATT, CE. *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results,* United States Department of Commerce Technology Administration, National Institute of Standards and Technology, September 1994, NIST Technical Note 1297.

[4] *Expression of the Uncertainty of Measurement in Calibration.* European Cooperation for Accreditation of Laboratories, EAL-R2, April 1997; and *Supplement 1 to EAL-R2,* EAL-R2-S1, November 1997.