Uncertainty in RF Emission measurements - Revision of CISPR 16-4-2

by

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Overview on Revision of CISPR 16-4-2

- Introduction – status of CISPR 16-4-2
- Concept of CISPR 16-4-2
  - Scope
  - Structure
  - Basic Rules
  - Influence of amendments to other basic standards (CISPR 16-1-2, CISPR 16-1-3 and CISPR 16-1-4)
- Extension of CISPR 16-4-2
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  - Specifics for conducted disturbance measurements
  - Specifics for radiated disturbance measurements at 3 m distance
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- Conclusions

Introduction: Status of CISPR 16-4-2

- First published as CISPR 16-4 in 2002 – a basic standard
- CISPR 16-4-2:2003 identical with CISPR 16-4:2002
- Applied by product standards: CISPR 11 (4th ed.) Amd 2:2006-06 and CISPR 22:2005-04 (5th ed.) - only a statement of U_{lab} in the test report is needed
- New proposals for full application of CISPR 16-4-2 in CISPR 14-1 and Generic Emission standards, i.e. to check whether U_{lab} exceeds U_{cispr}
- At present specifications for U_{cispr} are available only for three methods of measurement:
  - Conducted disturbance measurements at the mains port
  - Disturbance power measurements using the absorbing clamp
  - Radiated disturbance measurement on OATS and SAC in 30 to 1000 MHz

Concept of CISPR 16-4-2: Scope and Structure

- **Scope: Estimation and treatment of Measurement Instrumentation Uncertainty (MIU)**
  - **This includes:**
    - Contributions of the measuring receiver
    - Contributions of the ancillary equipment: Transducers (AMNs, voltage and current probes, absorbing clamps and antennas)
    - Contributions of the test sites including the test geometry
  - **This excludes:**
    - Reproducibility of the EUT
    - Uncertainties in the test specification (EUT setup, cable arrangement and measurement procedure)
    - Uncertainties caused by the test personnell
- **Structure**
  - A short normative section defining the basic rules and the list of influence quantities
  - A detailed informative annex for the background of U_{cispr} values

Concept of CISPR 16-4-2: Basic Rules

◆Key decision: Measurement instrumentation uncertainty shall be taken into account when determining compliance or non-compliance with a disturbance limit.
◆The measurement instrumentation uncertainty of a test laboratory shall be determined taking specified input quantities into account.
◆The standard uncertainty $u(x_i)$ in decibels and the sensitivity coefficients c_i shall be determined for the estimate x_i of each quantity. The combined standard uncertainty $u_c(y)$ of the estimate y of each measurement quantity shall be determined as follows:

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

◆The expanded measurement uncertainty U_{lab} of the test equipment of a test laboratory is calculated as (coverage factor 2 means a confidence level of 95%).

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

◆Using the influence quantities defined in CISPR 16-4-2, values of U_{cispr} have been calculated based on the tolerances given in the CISPR 16-1-x series

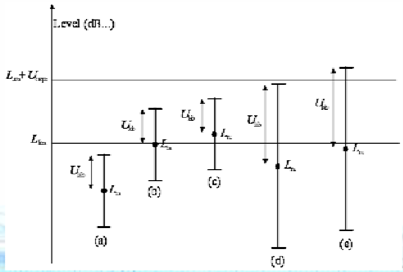
Concept of CISPR 16-4-2: Basic Rules

◆Values for U_{cispr}

Measurement of		U_{cispr}
Dist. Voltage (mains)	9 kHz - 150 kHz	4,0 dB
Dist. Voltage (mains)	0,15 - 30 MHz	3,6 dB
Dist. Power (Absorb. Clamp)	30 - 300 MHz	4,5 dB
Dist. Field Strength	30 - 1000 MHz	5,2 dB
Other measurements		under consideration

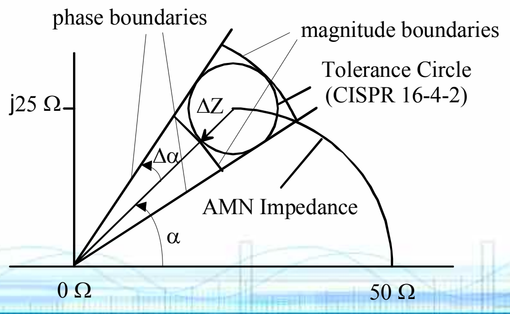
◆If $U_{lab} \leq U_{cispr}$ then compliance occurs, if no measured disturbance exceeds the limit.
◆If $U_{lab} > U_{cispr}$ then compliance occurs, if no measured disturbance increased by $U_{lab} - U_{cispr}$ exceeds the limit.

◆Cases c) and e) are not compliant!



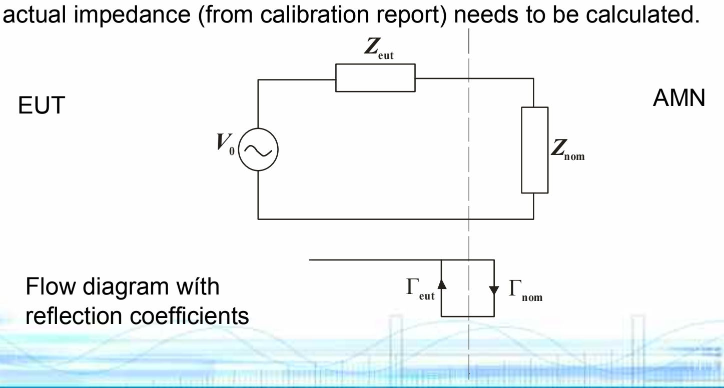
To account for amendments to basic standards

- After CISPR 16-4-2 had been published, some of the CISPR 16-1-x series were amended, which has to be taken into account in the revision.
- For conducted emission measurements at the mains port,
  U_{cispr} = 4,0 dB for 9 – 150 kHz and U_{cispr} = 3,6 dB for 0,15 bis 30 MHz
  Where the contribution of the AMN(LISN) impedance is 3,6 dB resp. 2,7 dB.
  Therefore it is worth-while to look at this contribution to U_{lab} more closely
- This results from the tolerance circle around the AMN impedance.



To account for amendments to CISPR 16-1-2

- Originally, CISPR 16-1-2 specified only a tolerance for the impedance magnitude. In CISPR 16-4-2 assumes a tolerance circle around the impedance. Therefore a tolerance of ±11,5 deg for the impedance phase was added to CISPR 16-1-2.
- For an estimate of the uncertainty, the maximum voltage deviation due to the actual impedance (from calibration report) needs to be calculated.



Flow diagram with reflection coefficients

To account for amendments to CISPR 16-1-2

For the reference AMN the voltage across the impedance (with Z_{nom} = 50 Ω//50 µH for 0,15 – 30 MHz and Z_{eut} = source impedance) is

$$V_{\text{nom}} = \frac{Z_{\text{nom}}}{Z_{\text{eut}} + Z_{\text{nom}}} V_0 = \frac{(1+\Gamma_{\text{nom}})(1-\Gamma_{\text{eut}})}{2(1-\Gamma_{\text{nom}}\Gamma_{\text{eut}})} V_0$$

For the real artificial network (AN) the deviation from Z_{nom} must be considered:

$$\Gamma_{\text{nom}} = \frac{Z_{\text{nom}} - Z_0}{Z_{\text{nom}} + Z_0} \qquad \Gamma_{\text{eut}} = \frac{Z_{\text{eut}} - Z_0}{Z_{\text{eut}} + Z_0} \qquad \Gamma_{\text{an}} = \frac{Z_{\text{an}} - Z_0}{Z_{\text{an}} + Z_0}$$

The maximum deviation from the magnitude is 20%, from the phase is 11,5º

$$V_{\text{an}} = \frac{Z_{\text{an}}}{Z_{\text{eut}} + Z_{\text{an}}} V_0 = \frac{(1+\Gamma_{\text{an}})(1-\Gamma_{\text{eut}})}{2(1-\Gamma_{\text{an}}\Gamma_{\text{eut}})} V_0$$

Voltage deviation: V_{an} and V_{nom} must be compared

To account for amendments to CISPR 16-1-2

◆The measured value of the AN impedance deviates from the nominal value which can cause a deviation from the nominal voltage (simplified assumption: EUT impedance is high) but also the EUT phase is important.

◆For a low impedance source (e.g. Z_{eut} = 0 Ω) the impedance deviation does not cause a voltage deviation

◆For the calculation of the voltage deviation caused by impedance deviation, magnitude and phase of the nominal impedance must be known (see tables in CISPR 16-1-2). A program was developed for the calculation of the maximum voltage deviation for measured values of the AN impedance.

$$\left|\frac{V_{\text{an}}}{V_{\text{nom}}}\right| = \left|\frac{1+\Gamma_{\text{an}}}{1-\Gamma_{\text{eut}}\Gamma_{\text{an}}} \cdot \frac{1-\Gamma_{\text{eut}}\Gamma_{\text{nom}}}{1+\Gamma_{\text{nom}}}\right|$$

$Z_{\text{an}} = Z_{\text{nom}} + \alpha|Z_{\text{nom}}|\exp(j\theta)$ with $0 \le \alpha \le 0{,}2$ and $0 \le \theta < 2\pi$

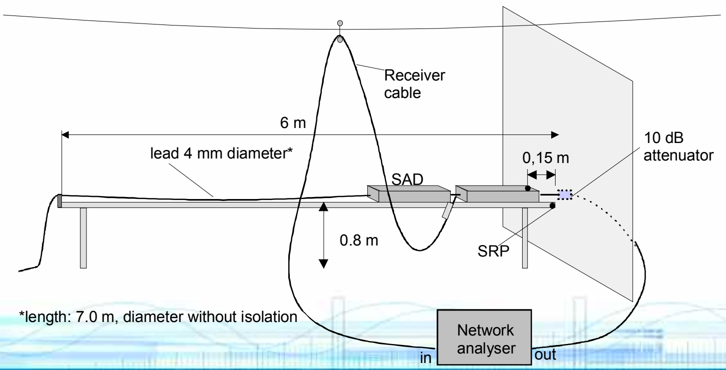
$\Gamma_{\text{eut}} = \rho\exp(j\phi)$ with $0 \le \rho \le 1$ and $0 \le \phi \le 2\pi$

To account for amendments to CISPR 16-1-2

Frequency	resistive	reactive	magnitude (nom.)	magnitude (act.)	Phase (act.).	Max. dev.
kHz	Ω	Ω	Ω	Ω	°	dB
9	4,66	2,33	5,21	4,71	+17,17	-1,63/0
15	4,69	2,58	5,36	6,55	+32,24	-0,74/0
20	5,13	5,13	7,25	7,20	+39,89	-0,91/0
50	7,97	12,00	14,41	13,74	+54,27	-0,90/0
70	10,81	15,67	19,04	18,16	+53,80	-0,79/0
100	15,73	19,5	25,11	23,90	+50,16	-0,69/0
150	23,79	22,46	32,72	31,25	+42,84	-0,51/0
159	25,00	25,00	35,35	32,36	+41,99	-0,44/0
200	30,61	24,36	39,12	36,11	+36,54	-0,44/0
500	45,40	14,45	47,64	45,76	+18,01	-0,27/0
700	47,54	10,81	48,76	47,21	+13,30	-0,24/0
1000	48,76	7,76	49,38	48,06	+9,67	-0,22/0
2000	49,69	3,95	49,64	48,77	+5,52	-0,20/0
5000	49,95	1,59	49,97	49,14	+3,87	-0,24/0
7000	49,97	1,14	49,99	49,35	+4,24	-0,40/0
10000	49,99	0,79	49,99	49,59	+4,60	-0,30/0
15000	49,99	0,53	50,00	49,94	+5,86	0/+0,42
20000	50,00	0,40	50,00	50,39	+6,76	0/+0,54
25000	50,00	0,32	50,00	50,45	+7,72	0/+0,64
30000	50,00	0,27	50,00	50,51	+8,42	0/+0,71

To account for amendments to CISPR 16-1-3

- In disturbance power measurements, apart from the uncertainty of the clamp factor itself, a strong influence is caused by the environment, i.e. the absorbing clamp test site.
- Therefore a validation method has been developed and published in CISPR 16-1-3, where the clamp factor measured in situ is compared to the clamp factor measured on a reference site.



To account for amendments to CISPR 16-1-4

- In radiated disturbance measurements on the OATS/SAC the antenna factor height dependence below 200 MHz was treated as the difference between the height dependence of the former reference antenna (tuned dipole) and the actual measuring antenna.
- The reference antenna was however replaced by the electric field strength in CISPR 16-1-4. This will require the a revision of the influence quantity antenna factor height dependence.
- Further, the shape, construction and material permittivity of an EUT setup table can influence field-strength measurement results. This will have to be regarded as an influence quantity.
- For an estimate of the amount of uncertainty, the evaluation procedure for setup table influences described in CISPR 16-1-4 must be used. This procedure compares two transmission measurements with a broadband transmit antenna close to the setup table and with the setup table removed.

Extension of CISPR 16-4-2: Inclusion of further emission test methods

- The three test methods in the current CISPR 16-4-2 are only a subset of the emission test methods used in EMC laboratories. Therefore CISPR/A has agreed to include further test methods in the next edition:
- For conducted emission measurements:
  - Using a voltage probe on the power port
  - Using an asymmetric artificial network on the telecommunication port
  - Using a capacitive voltage probe on the telecommunication port
  - Using a current probe on the telecommunication port
- For radiated emission measurements
  - Using a fully anechoic room in the frequency range from 30 to 1000 MHz
  - Using a fully anechoic room in the frequency range from 1 to 18 GHz
- This requires restructuring of both, the normative body and the informative annexes. In addition many details have to be revised.

Extension: inclusion of methods using voltage and current probes

- The AMN impedance tolerance is a relatively large source of uncertainty in conducted emission measurement methods.
- The influence of the impedance of current and voltage probes is comparatively small (2,9 dB for voltage and current probes compared to 3,6 dB or even 4 dB for the AMN and up to 4,8 dB for the AAN)
- This should not cause standard writers and test laboratories to replace the AMN by the voltage probe and the AAN by the current probe, as there is no decoupling between the EUT port and the mains port (respectively the AE port) of the coupling unit.
- No decoupling means that the measurement result may strongly be influenced by the impedance of the mains, repectively of the auxiliary equipment (AE). Compared to measurements using the AMN or the AAN, the estimated compliance uncertainty my rise by a factor of 6.

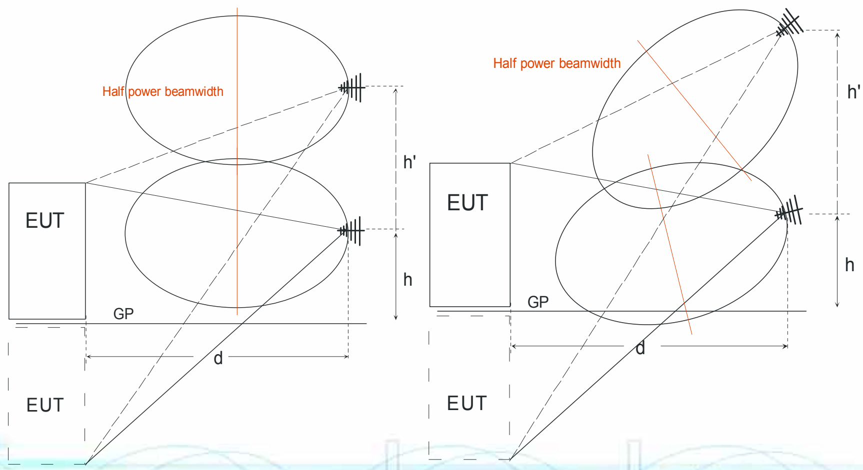
Extension: inclusion of the method using an Asymmetrical Artificial Network (AAN, ISN)

- For the measurement of conducted emissions on unshielded telecommunication ports, CISPR 22 specifies the AAN (ISN)
- One source of uncertainty is the asymmetric AAN impedance tolerance – it affects the launched common mode disturbance
- Another source of uncertainty is the longitudinal conversion loss (LCL) tolerance of the AAN – it affects the converted common mode disturbance of the EUT.
- The LCL tolerance is dependent on the frequency range and on the specified LCL. It is
  - ± 3 dB for an LCL of 55 dB at 150 kHz falling to 40 dB at 30 MHz
  - Up to +6/-3 dB for an LCL of 75 dB at 150 kHz falling to 60 dB at 30 MHz
- Both sources of uncertainty are independent of each other
- A triangular probability distribution may be assumed for both cases

Extension: effect of antenna directivity for radiated emission measurements at 3 m

- The effect of antenna directivity has been treated already in CISPR 16-4-2 ed. 1, but a closer look results in a higher uncertainty
- CISPR 16-1-4 recommends that the antenna responses in the direction of direct ray and the reflected ray be within 2 dB of the antenna boresight.
- For measurement distances of 30 m and 10 m, this is usually true. For 3 m distance either antenna down-tilting shall be applied or the average reduction of received signal shall be calculated and applied as correction of the measurement result.
- An increased uncertainty will result, if downtilting is not applied
- This directivity problem exists despite the fact that measurements at 3 m distance are not normative in CISPR 11 and CISPR 22
- Also the problem could be minimized by using antennas with lower directivity, as the sensitivity problem does not exist at 3 m distance

Extension: effect of antenna directivity for radiated emission measurements at 3 m



Extension: inclusion of radiated emission measurements in the fully anechoic room (FAR)

- Regarding measurement uncertainties, the FAR has several advantages over the OATS/SAC:
  - Uncertainties due to antenna directivity are much smaller
  - Antenna tilting is not required
  - Uncertainties due to near-field effects are much smaller as the EUT mirror does not exist
  - Antenna factor height dependence does not exist – only a small influence of the FAR walls
  - Site imperfections are in the same order of magnitude as on the OATS/SAC
- The FAR does not require antenna height scanning
- In addition, the FAR allows emission and immunity measurements with a uniform EUT arrangement

Extension: inclusion of radiated emission measurements in the FAR above 1 GHz

- The measurand for radiated emission measurements from 1 to 18 GHz is the field strength at 3 m distance. This solves the near-field problem for this (reference) distance.
- For other distances, there is an uncertainty due to near-field effects
- Usually above 1 GHz, external preamplifiers close to the antenna are used. Therefore it is necessary to
  - Account for mismatch uncertainty twice: antenna/preamp and preamp/receiver
  - Calculate the system noise figure for the uncertainty due to the effects of noise
- For the uncertainty due to site imperfections, the basis is the site validation method using the site voltage standing wave ratio ($s_{vswr} \leq 6$ dB)
- In a CISPR/A WG document it has been shown that an s_{vswr} of 6 dB corresponds to a maximum deviation of the transmission loss of 4 dB from the ideal. Since the 4 dB criterion is not exceeded anywhere, the criterion is fulfilled with a confidence level of 99,7% (k = 3), u = 1,3 dB

Conclusions on Revision of CISPR 16-4-2

The amendment of CISPR 16-4-2 consists of many details

- The basic principles will be kept
- Existing material will be revised
- New test methods for conducted and radiated emissions will be added
- This requires a new structure
  - The normative part will consist of the table with U_{cispr} values and lists of input quantities in separate clauses and subclauses for each type of test
  - The informative annexes will consist of tables with the uncertainty budgets as background information for the derivation of U_{cispr}
  - Also the annexes contain the necessary explanation to help test labs do their own estimate of uncertainty
- Measurands for each test are defined as it is important to avoid misunderstandings
- Due to time limitations, not all details have been presented here