CISPR 16-4-3

Edition 2.1 2007-01

TECHNICAL REPORT

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Specification for radio disturbance and immunity measuring apparatus and methods –
Part 4-3: Uncertainties, statistics and limit modelling – Statistical considerations in the determination of EMC compliance of mass-produced products

CISPR 16-4-3/TR:2004+A1:2006(E)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.100.10; 33.100.20

ISBN 2-8318-8915-4

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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CISPR 16-4-3, which is a technical report, has been prepared by CISPR subcommittee A: Radio interference measurements and statistical methods.

This second edition of CISPR 16-4-3 cancels and replaces the first edition published in 2003 and constitutes a technical revision. It includes a new mathematical approach for the application of the 80%/80% rule, based on a method involving an additional acceptance limit. The mathematical basis for this new method is also provided. Furthermore, an additional test approach, based on the non-central *t*-distribution and using frequency sub-ranges has been added as well, along with a description of the properties of all methods which are available at this point in time.

This consolidated version of CISPR 16-4-3 consists of the second edition (2004) [documents CISPR/A/491/DTR + CISPR/A/492/DTR and CISPR/A/507/RVC + CISPR/A/508/RVC] and its amendment 1 (2006) [documents CISPR/A/666/DTR and CISPR/A/691/RVC].

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience.

It bears the edition number 2.1.

A vertical line in the margin shows where the base publication has been modified by amendment 1.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendments 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- withdrawn,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.

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 4-3: Uncertainties, statistics and limit modelling – Statistical considerations in the determination of EMC compliance of mass-produced products

1 Scope

This part of CISPR 16 deals with statistical considerations in the determination of EMC compliance of mass-produced products.

The reasons for such statistical considerations are:

a) that the abatement of interference aims that the majority of the appliances to be approved shall not cause interference;

b) that the CISPR limits should be suitable for the purpose of type approval of mass-produced appliances as well as approval of single-produced appliances;

c) that to ensure compliance of mass-produced appliances with the CISPR limits, statistical techniques have to be applied;

d) that it is important for international trade that the limits shall be interpreted in the same way in every country;

e) that the National Committees of the IEC which collaborate in the work of the CISPR should seek to secure the agreement of the competent authorities in their countries.

Therefore, this part of CISPR 16 specifies requirements and provides guidance based on statistical techniques. EMC compliance of mass-produced appliances should be based on the application of statistical techniques that must reassure the consumer, with an 80 % degree of confidence, that 80 % of the appliances of a type being investigated comply with the emission or immunity requirements. Clause 4 gives some general requirements for this so-called 80 %/80 % rule. Clause 5 gives more specific requirements for the application of the 80 %/80 % rule to emission tests. Clause 6 gives guidance on the application of the CISPR 80 %/80 % rule to immunity tests. The 80 %/80 % rule protects the consumer from non-compliant appliances, but it says hardly anything about the probability that a batch of appliances from which the sample has been taken will be accepted. This acceptance probability is very important to the manufacturer. In Annex A, more information is given on acceptance probability (manufacturer's risk).

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.

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*
Amendment 1 (1997)
Amendment 2 (1998)

CISPR 16-4-2, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics and limit modelling – Uncertainty in EMC measurements*

3 Terms, definitions and symbols

For the purpose of this document, the terms, definitions and symbols given in IEC 60050-161 apply.

4 General requirements

The following interpretation of CISPR limits and of methods of statistical sampling for compliance of mass-produced appliances with these limits should be applied.

4.1 Limits

4.1.1 A CISPR limit is a limit that is recommended to national authorities for incorporation in national standards, relevant legal regulations and official specifications. It is also recommended that international organizations use these limits.

4.1.2 The significance of the limits for type-approved appliances shall be that, on a statistical basis, at least 80 % of the mass-produced appliances comply with the limits with at least 80 % confidence.

4.2 Type testing approaches

Type tests can be made using the following two approaches.

4.2.1 Use of a sample of appliances of the same type

When using this approach, the sample of appliances of the same type shall be evaluated statistically in accordance with the methods described in Clause 5 (emission tests) and Clause 6 (immunity tests).

Statistical assessment of compliance with limits shall be made according to the methods described in Clauses 5 and 6 or in accordance with some other method that ensures compliance with the requirements of clause 4.1.2.

4.2.2 Use of a single device with subsequent quality assurance testing

For simplicity, a type test can be performed initially on one item only. However, subsequent tests from time to time on items taken at random from the production are necessary.

4.2.3 Withdrawal of the type approval

In the case of controversy involving the possible withdrawal of a type approval, withdrawal shall be considered only after tests on an adequate sample in accordance with 4.2.1 above.

5 Emission measurements

Statistical assessment of compliance with emission limits shall be made according to one of the three tests described below or to some other test that ensures compliance with the requirements of 4.1.2.

5.1 Test based on the non-central *t*-distribution.

This test should be performed on a sample of not less than five items of the type, but if, in exceptional circumstances, five items are not available, then a sample of three shall be used. Compliance is judged from the following relationship:

$$\bar{x}_n + kS_n \leq L \qquad (1)$$

where

$\bar{x}_n$ = arithmetic mean value of the levels of *n* items in the sample;

$$S_n^2 = \sum\left(x - \bar{x}_n\right)^2 / (n-1); \qquad (2)$$

x = level of individual item;

k = the factor derived from tables of the non-central *t*-distribution with 80 % confidence that 80 % of the type is below the limit; the value of *k* depends on the sample size *n* and is stated below:

N	3	4	5	6	7	8	9	10	11	12
k	2,04	1,69	1,52	1,42	1,35	1,30	1,27	1,24	1,21	1,20

L = the permissible limit;

the quantities x, $\bar{x}_n$, S_n and L are expressed logarithmically dB(μV), dB(μV/m) or dB(pW);

If one or some appliance of the sample can not be measured due to the insufficient sensitivity of the test equipment, Annex B describes an approach to solve this situation.

5.1.1 Tests using sub-ranges

5.1.1.1 Introduction

The 80 %/80 % rule shall be used for the specific emission at a specific frequency or frequency range at each EUT of the sample. Modern computer-controlled measurement equipment usually scans the frequency range and measures a limited number of the highest disturbances at certain frequencies of the whole emission spectrum. Because the level of the disturbance at the same frequency or the frequency at the highest emission varies from EUT to EUT, the measured frequencies of the highest disturbance levels usually vary from one EUT to another in a sample. These measurement results cannot be used for the 80 %/80 % rule because one does not obtain measurement levels at approximately the same frequency for each EUT to calculate the average and standard deviation of the EUT's level. For this reason, it is useful to divide the whole frequency range into defined sub-ranges, which allow a statistical analysis of the emission spectrum in the whole frequency range by taking the highest measured level in each sub-range.

For the application of the non-central *t*-distribution in the 80 %/80 % rule, it is necessary to normalise the measured values. These normalised values allow the use of the 80 %/80 % rule in the sub-ranges independently of variations of the limit in a sub-range.

The whole frequency range shall be divided on a logarithmic frequency axis into sub-ranges. The border of the sub-ranges may correspond to changes in limits, if a product committee so requires.

NOTE The division of the frequency range into sub-ranges is applicable only to the test based on the non-central *t*-distribution.

5.1.1.2 Number of sub-ranges

It is suggested that the frequency range of the disturbance measurement method in question is divided into a number of frequency sub-ranges. The span of each frequency sub-range should decrease in a logarithmic way as a function of the frequency. For the different disturbance measurement methods, the following number of sub-ranges is suggested:

– at least 8 sub-ranges in the frequency range of up to 30 MHz for the measurement of the disturbance voltage;
– at least 4 sub-ranges in the frequency range from 30 MHz to 300 MHz for the measurement of the disturbance power, and

– about 8 sub-ranges in the frequency range from 30 MHz to 1000 MHz for the measurement of disturbance field strength.

NOTE 1 The number of sub-ranges shall be determined such that the frequency dependence of the disturbance's characteristic can be estimated. This condition is fulfilled if the ratio of limit to average plus standard deviation of the emission in the sub-ranges does not decrease when the number of sub-ranges is reduced.

NOTE 2 The product committees should determine the number of sub-ranges depending on the disturbance characteristics of the different products.

NOTE 3 The recommended number of sub-ranges is based on the investigations of samples of CISPR 14 and CISPR 22 devices.

NOTE 4 The sub-range transition frequency can be calculated as follows:

$$f = f_{\mathrm{low}} \times 10^{\frac{i}{\mathrm{N}} log\left(\frac{f_{\mathrm{upp}}}{f_{\mathrm{low}}}\right)}$$

where

i = 1 ... N is the index of the i-th sub-range transition frequency;

f_{low}, f_{upp} are the lower and upper frequency of the frequency range;

N= is the number of frequency sub-ranges.

NOTE 5 For predominantly narrow band emission it is possible to select single narrow band emission by preexamination for the use of the non-central t-distribution without using sub-ranges.

5.1.1.3 Normalization of the measured disturbance levels

The average value and the standard deviation of the measured values in a frequency sub-range shall be compared to the limit. Because the limit may not be constant over the frequency sub-range, it is necessary to normalize the measured values.

For normalization, the difference, d_{f}, between the measured level, x_{f}, and the limit level, L_{f}, shall be determined at the specific frequency f that has the largest difference, using Equation (3). The difference is negative as long as the measured value is below the limit.

$$d_{\mathrm{f}} = x_{\mathrm{f}} - L_{\mathrm{f}} \tag{3}$$

where

d_{f} = the gap to the limit at the specific frequency in dB;

x_{f} = the measured level in dB(µV or pW or µV/m);

L_{f} = the limit at the specific frequency in dB(µV or pW or µV/m).

5.1.1.4 Tests based on the non-central *t*-distribution with frequency sub-ranges

As a result of the measurement of all pieces of the sample for each sub-frequency range, the average and the standard deviation of the gap d_{f} shall be calculated. The average of the gap is

$$\overline{d}_{\mathrm{f}} = \frac{1}{n}\sum_{n} d_{\mathrm{f}} \tag{4}$$

where

n = the number of items in the sample

$\overline{d}_{\mathrm{f}}$ = the average gap in the sub-range and the standard deviation is

$$S_{df} = \frac{1}{\sqrt{n-1}} \sqrt{\sum_{n} (d_f - \bar{d}_f)^2} \qquad (5)$$

where S_{df} = the standard deviation in the sub-range.

Compliance is judged from the following relationship:

$$\bar{d}_f + k \cdot S_{df} \leq 0 \qquad (6)$$

k: see 5.1 above.

5.2 Test based on the binomial distribution

This test should be performed on a sample of not less than seven items. Compliance is judged from the condition that the number of appliances with an interference level above the permissible limit may not exceed *c* in a sample of size n.

n	7	14	20	26	32
c	0	1	2	3	4

5.3 Test based on an additional acceptance limit

This test should be performed on a sample of not less than five items of a particular type, but if, in exceptional circumstances, five items are not available, then a sample of at least three shall be used. Details on this method are described in 5.5. Compliance is judged if every measured disturbance level x_i satisfies the following relation:

$$x_i \leq AL = L - \sigma_{max} \cdot k_E \qquad (7)$$

where

AL is the acceptance limit

L is the permissible limit

σ_{max} is the expected maximum standard deviation of the product, which is 2 times the expected standard deviation, and which is determined by the product committee using the procedure of 5.3.1 or alternatively the following conservative values for the different types of disturbance measurements can be used:

disturbance voltage: σ_{max} = 6 dB*)

disturbance power: σ_{max} = 6 dB**)

disturbance field strength: σ_{max} = xx dB[1]

NOTE 1 The values of 6 dB were determined by measurements of 130*) and 40**) different EUT types (3 or 5 samples each). The value of 6 dB was estimated by comparing the tests using the non-central *t*-distribution with the tests using the additional margin. Both tests give about the same percentage of approvals.

NOTE 2 The disturbance field strength value is under consideration.

———————

[1] Under consideration

k_E is the factor derived from tables of the normal distribution with 80 % confidence that 80 % of the type is below the limit; the value of k_E depends on the sample size n and is stated below (see Annex C.1):

n	3	4	5	6
k_E	0,63	0,41	0,24	0,12

The quantities x, L, k_E and σ_{max} are expressed logarithmically as dB(µV), dB(µV/m) or dB(pW).

NOTE With σ_{max} = 6 dB the following additional acceptance limit will be calculated:

Sample size	3	4	5	6
additional acceptance limit [dB]	3,8	2,5	1,5	0,7

5.3.1 Estimation of the maximum expected standard deviation

The expected standard deviation of disturbance emission shall be determined by an efficient number of samples of the product concerned. The following procedure is recommended:

On each investigated frequency or in each frequency sub-range in the sample being investigated, the difference x_{min} between the measured maximum emission x_i and the limit L shall be determined

$$x_{min} = (x_i - L)_{max} \tag{8}$$

The standard deviation S_{sub} of the differences in a sub-range or investigated frequency of a sample shall be calculated

$$S_{sub} = \frac{1}{\sqrt{n-1}}\sqrt{\sum_n (x_{min} - \bar{x}_{min})^2} \tag{9}$$

where n is the number of appliances in the sample.

The average standard deviation $\bar{S}_{sample}$ over the sub-ranges shall be determined for each sample. The expected standard deviation S_{expect} is the average over $\bar{S}_{sample}$ of all samples.

The maximum expected standard deviation is two times the expected standard deviation.

NOTE The factor of two is chosen by comparison of the test methods using the additional margin and the non-central *t*-distribution. Both test methods have, with the factor two, approximately the same rejection rate of samples.

Product committees may verify the expected standard deviation of their products.

5.4 Additional sampling in case of non-compliance

Should the test on the sample result in non-compliance with the requirements in 5.1, 5.2 or 5.3, then a second sample may be tested and the results combined with those from the first sample and compliance checked for the larger sample. For 5.3 this method is only applicable to samples of 7 or less appliances.

5.5 Properties of the different methods that can be used

The possible four test methods for compliance evaluation of mass products are:

- using a single device,
- non-central *t*-distribution (see 5.1),
- binomial distribution (see 5.2) and
- the additional margin (see 5.3)

Each of these methods are based on different statistical methodologies, and therefore each of the methods have different properties (advantages or disadvantages) when applied in practice by manufacturers or authorities.

a) Using a single device

A test on a single device is used by manufacturers. The method requires that repetitive testing of the product over time has to occur.

b) Non-central *t*-distribution:

The test is based on the non-central *t*-distribution and contains the condition of normal distribution for the totality. As long as this condition is fulfilled, the test gives correct results for the approval of a sample. But disapproval may be indicated without reason if one or two measurements are far below the limit and the other measurement results are near (but below) the limit.

If the failure is caused by measurement results far below the limit due to the large standard deviation, alternatively the test with the additional margin may be used for the failed sample. If the sample passes, the product is o.k.

In case of disapproval, it is possible to select further devices from the same product batch and to combine all the failed and newly selected devices in a larger sample.

An advantage of this test method is that the sample can be relatively small.

c) Binomial distribution:

The test is based on the binomial distribution and contains no further condition of distribution for the totality. The test gives correct results for the approval and disapproval of a sample.

In case of disapproval, it is possible to select further devices from the same product batch and to combine all the failed and newly selected devices in a larger sample.

The disadvantage of this test method is that the sample must have at least 7 devices.

d) Additional acceptance limit:

The test is based on the condition of normal distribution for the totality and the estimation of the expected standard deviation. The test gives correct results for the approval of a sample.

If the failure is caused by measurement results which are close to the limit, an additional test on the sample based on the non-central *t*-distribution may be used for the failed sample. If the sample passes the test, the product is o.k.

In case of disapproval, it is possible to select further devices from the same product batch and to combine all the failed and newly selected devices in a larger sample. This method is only applicable to samples with less than 7 devices.