TECHNICAL REPORT

CISPR 16-4-3

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AMENDMENT 1
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INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Amendment 1

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

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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/666/DTR	CISPR/A/691/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- withdrawn,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.

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CONTENTS

Add the title of new Annex D as follows:

Page 7

5.1.1.2 Number of sub-ranges

Replace the formula in NOTE 4, on page 8, by the following:

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

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5.1.1.3 Normalization of the measured disturbance levels

Replace the existing text of the subclause by the following:

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.

$$d_f = x_f - L_f \tag{3}$$

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

After Equation (4) replace the line beginning "n = ..." by the following:

"*n* = the number of items in the sample"

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Add, after Annex C, the following new annex:

Annex D
(informative)

Estimation of the acceptance probability of a sample

D.1 Introduction

The following considerations are intended for use by manufacturers to estimate the real acceptance probability of a sample, i.e. the manufacturers' risk to fail a market surveillance test. These considerations are based on the assumption that a realistic standard deviation for the specific type of equipment under test can be estimated based on the experience of the manufacturer with a specific class of products. The considerations in this annex can also be used to estimate a margin to the limit, which is needed to achieve a desired acceptance probability. It is emphasized that the purpose of this annex is to provide tools to manufacturers for estimation of their own risk, but without introducing additional requirements.

For both the realistic standard deviation and the target acceptance probability, exact values can be defined only by the manufacturer. Therefore, these methods cannot be used to add an additional margin to the limit as a Pass/Fail criterion for tests performed by organizations other than the manufacturers.

The acceptance probability relationships provided in this document do not include consideration of measurement uncertainties, as described in CISPR 16-4-1 and CISPR 16-4-2. In some cases, these uncertainties can dominate interlaboratory comparisons. As such, the acceptance probability calculations below are valid only when results differing from each other within the measurement uncertainty of the original test are considered to be equivalent.

Figure D.1 shows the normalized (standard deviation σ = 1,0) distribution of the amplitude density of the disturbance values for a population exactly at the acceptance limit, which means 80 % of the values are under the disturbance limit, and 20 % are over the disturbance limit. In this figure the disturbance limit has been shifted to the origin of the coordinate system, to allow easier calculation of the difference from the limit.

To pass a statistical evaluation based on the binomial distribution, for seven devices taken randomly out of this population, the largest measured value must still be below the interference limit. The curve labeled $n = 7$ in Figure D.1 shows this probability, which is just 20 % at the disturbance limit (the origin of the coordinate system) for the given population. In this case the acceptance probability is 20 %.

NOTE An acceptance probability of exactly 20 % in this case is not coincidental – it comes from the requirement to guarantee an 80 % confidence level for the method, based on the binomial distribution.

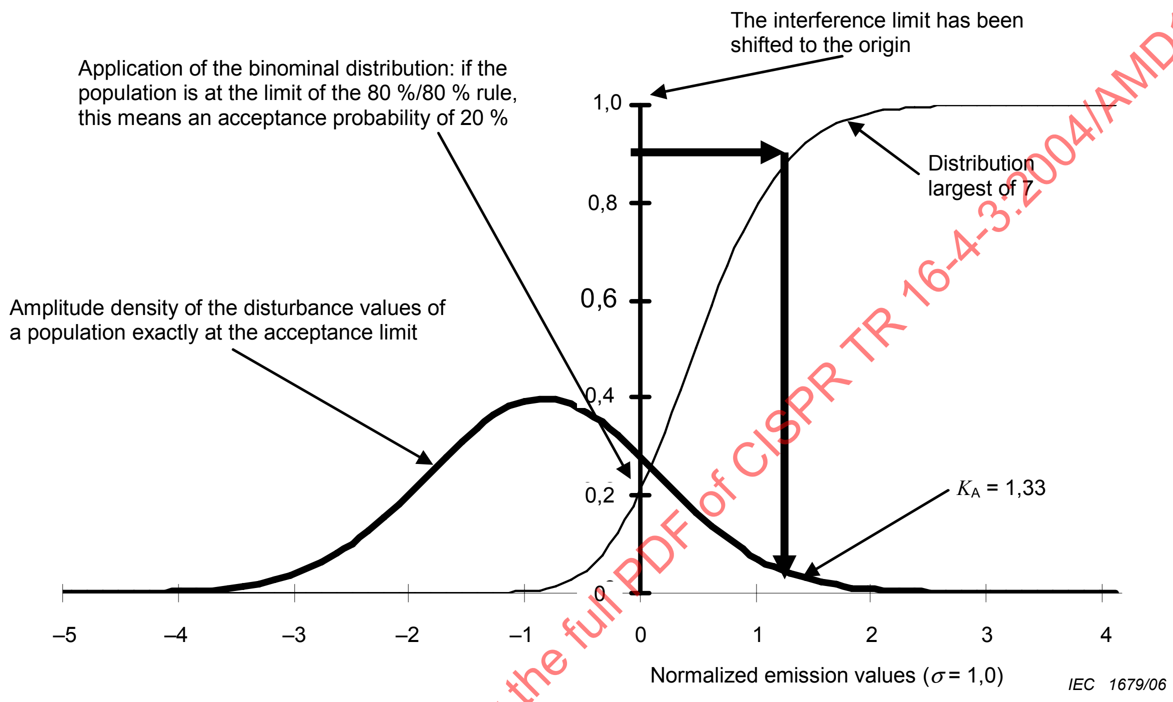


Figure D.1 – Normalized distribution (standard deviation $\sigma = 1,0$) for the amplitude density of the disturbance values

The black arrows indicate how an additional distance to the limit could be selected to increase the acceptance probability. To realize an acceptance probability of about 90 % for a test with a sample size of seven, all normalized emission values should be reduced by a value K_A of about 1,33, which would shift both curves to the left by 1,33. Then the curve labeled $n = 7$ would intersect the ordinate at about 0,9, meaning the probability that all values are below zero is about 90 %. This approach is similar to the methodology used in [4][1], and in CISPR 16-4-3, 5.3 and Annex C, respectively.

The problem with the preceding approach is that knowledge about the true values for the average and the standard deviation of the population are assumed. But the manufacturer does not know the true values, only the results from the sample tested. These results have the same random variation as a later sample would, when being tested for market surveillance purposes. In practice, the manufacturer has to infer from the sample tested what results can be expected for a possible sample tested later. Therefore, another approach has been chosen for the estimation of the acceptance probability, described in Clause D.2.

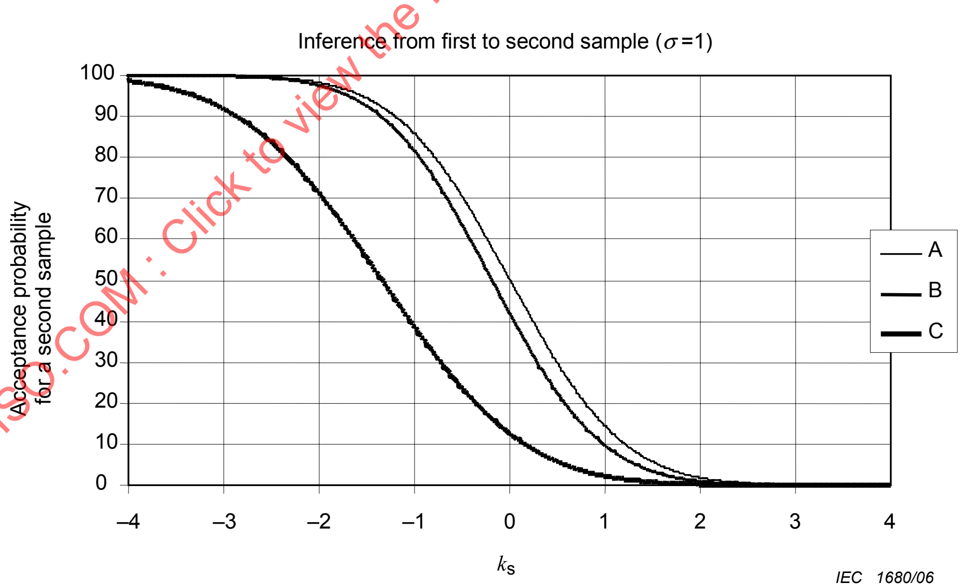
[1] Figures in square brackets refer to the reference documents in Clause D.6.

D.2 Estimation of the acceptance probability

The following approach is recommended to infer from existing sample test results what results can be expected for a possible sample tested later. Using an assumption of a normal distribution for the disturbance values, it is possible by simulation, or integration over the distribution functions, to determine the distribution of the difference between the maximum values of both samples. Consequently the acceptance probability for the second sample can be obtained, as shown in Figure D.2 and described in the following. In Figure D.2, and also the subsequent Table D.1, n_1 is the number of EUTs tested in the first sample (i.e. in the testing done by the manufacturer), n_2 is the number of EUTs tested in the second sample (e.g. during a market surveillance), and k_s is a factor used for the estimation of the acceptance probability. The curves shown are normalized, with standard deviation $\sigma = 1{,}0$.

The term n_1 in Figure D.2, and Table D.1, represents the number of EUTs tested. If the EUTs are from the same population and are tested under the same conditions, the probability is exactly 50 % that a second sample tested is at least as good as the first. Therefore a manufacturer can assume an acceptance probability of 50 % for a later test, if the manufacturer's sample is exactly at the acceptance limit, i.e. where the requirements in the standard are just fulfilled. If the sample tested by the manufacturer is better, then the acceptance probability for a later sample is higher than 50 %.

The curve labeled A in Figure D.1, having n_1 = 5 and n_2 = 5, is calculated assuming that both samples are tested according to the same method, and based on the calculation for an additional, different acceptance limit. Calculations can also be done for different sample sizes. Figure D.2 shows also the curve B (n_1 = 5, n_2 = 7), which is applicable when a later market surveillance is based on the binomial distribution. Finally, curve C (n_1 = 1, n_2 = 7) may be interesting for a manufacturer who has tested only one prototype, and is useful to estimate the acceptance probability of a sample during a later market surveillance.



Key

A n_1 = 5; n_2 = 5
B n_1 = 5; n_2 = 7
C n_1 = 1; n_2 = 7

Figure D.2 – Acceptance probability for a second sample

Table D.1 shows the values for a factor k_S which can be used to estimate the acceptance probability for a second sample following a test on a first sample with n_1 = 5 or n_1 = 1. The factor k_s can be used in two different ways:

– to estimate the acceptance probability for a repeated statistical evaluation after evaluating a first sample;

– to define a margin to the limit, necessary to reach a desired acceptance probability.

Examples showing both applications are given in D.4. In these applications, an estimation of a realistic standard deviation, σ_R, is needed for the type of EUT being investigated, which must be obtained by the manufacturer based on experience with similar products.

Table D.1 – Values of the factor k_S used to obtain acceptance probabilities

Row	n	k_S for an acceptance probability of:										
		99 %	98 %	97 %	95 %	90 %	85 %	80 %	75 %	70 %	60 %	50 %
A	n_1 = 5, n_2 = 5	–2,22	–1,95	–1,78	–1,55	–1,21	–0,97	–0,79	–0,63	–0,49	–0,24	0,00
B	n_1 = 5, n_2 = 7	–2,34	–2,08	–1,91	–1,69	–1,35	–1,13	–0,95	–0,80	–0,66	–0,42	–0,19
C	n_1 = 1, n_2 = 7	–4,15	–3,81	–3,59	–3,31	–2,87	–2,57	–2,34	–2,14	–1,96	–1,64	–1,34

NOTE The calculation with n_2 = 5 is based on the new method with an additional acceptance limit, introduced in CISPR 16-4-3, while the calculation with n_2 = 7 is based on the use of the binomial distribution.

D.3 Derivation of the factor k_s

The values for the factor k_S in Table D.1 were derived as follows. Assume, the measured values are normally distributed with density $g(x)$ and distribution function $G(x)$. Then in the sample n_1 taken by the manufacturer, the distribution function for the highest value is given by $[G(x)]^{n_1}$ and its density is therefore $n_1 g(x)\cdot[G(x)]^{n_1-1}$. Similarly, in the sample n_2 taken by the testing authority, the distribution function of the highest value is given by $[G(y)]^{n_2}$ and its density is therefore $n_2 g(y)\cdot[G(y)]^{n_2-1}$.

Setting $y = x + \delta$, the density of the distribution of δ (the difference between the highest result of the manufacturer and the highest result of the testing authority) is therefore

$$f(\delta) = n_1 n_2 \cdot \int_{-\infty}^{\infty} g(x)\cdot[G(x)]^{n_1-1}\cdot g(x+\delta)\cdot[G(x+\delta)]^{n_2-1}dx$$

Thus, if the highest result of the manufacturer is a margin D below the limit, the probability of the highest result of the testing authority being below the limit (i.e. test successful) is given by

$$\int_{-\infty}^{D} f(\delta)\cdot d\delta$$

To obtain the preceding table and figure, this integral was evaluated numerically.

D.4 Emissions near the limit at more than one frequency

The calculations in this annex are based on the use of the binomial distribution, i.e. on the method described in 5.3 of CISPR 16-4-3 (test based on an additional acceptance limit). For this condition, only the single emission value nearest to the limit is considered. If results are near the limit at more than one frequency, the frequency having the worst-case result shall be evaluated, bearing in mind that the actual standard deviation may be different at different frequencies.

D.5 Application examples

D.5.1 Application example No.1

A manufacturer wants to estimate the acceptance probability to be expected in a market surveillance based on measurements of a single prototype. The smallest difference between the measured result and the limit is 4,5 dB at one specific frequency. From previous experience, a realistic standard deviation of σ_R = 2,0 dB can be estimated for this frequency. Because the factors k_S were calculated for $\sigma = 1$, the measured value must be normalized. The existing normalized margin to the limit is therefore

$$4{,}5 \text{ dB} / \sigma_R = (4{,}5/ 2{,}0) = 2{,}25.$$

From row C in Table D.1, and using Figure D.2, the acceptance probability in this case is between 75 % and 80 %. If the manufacturer is not satisfied with this result, either more EUTs need to be tested to obtain a more precise estimate, or the margin to the limit must be increased (i.e. modify the product).

NOTE In this example n_2 = 7 was used, because in case of dispute, a sample of 7 or more typically is tested.

D.5.2 Application example No. 2

The limit for a certain product at a certain frequency is L = 50 dB. A manufacturer tests a sample consisting of 5 EUTs. From experience, at this test frequency the manufacturer can assume a realistic standard deviation of σ_R = 3,0. The factor k_S is given in Table D.1 row B. For a desired acceptance probability of 90 %, k_S = –1,35. Therefore the highest disturbance value in the manufacturer's sample of 5 must be less than

$$(50 - 1{,}35 * 3) \text{ dB} = 46 \text{ dB}.$$

If the manufacturer desires an acceptance probability of 99 %, the highest value in the sample must not exceed

$$(50 - 2{,}34 * 3) \text{ dB} = 43 \text{ dB}.$$

NOTE For this example it is recommended to use the Table D.1 row with n_2 = 7, because this allows a direct comparison with the limit, and gives better numbers for the manufacturer than using n_2 = 5. If a Table D.1 row with n_2 = 5 is used, only the margin necessary from the additional acceptance limit can be calculated (see CISPR 16-4-3). The overall margin to the real limit will be larger than it would with n_2 = 7.

D.6 References

[1] JOHNSON, NL., and LEONE, FC., *Statistics and Experimental Design*. Wiley and Sons: New York, 1964, pp. 298 – 348,.

[2] WILRICH, P-Th. Qualitätsregelkarten bei vorgegebenen Grenzwerten. *Qualität und Zuverlässigkeit*, Munich-Vienna: Carl Hanser Verlag, 1979, vol. 24, pp. 260-271.,.

[3] DETER, F., DUNKER, L. and KLEPPMANN, W. *New method for the statistical evaluation of RFI measurements.* EMC Zurich, 2003.

[4] CISPR/A/491/DTR "*Rules for applying the statistical 80/80 rule and use of partial frequency ranges*," accepted and included into CISPR 16-4-3, 2004.

[5] DETER, F., DUNKER, L., and KLEPPMANN, W. *Neue Verfahren zur statistischen Auswertung von Funkentstörmessungen unter Berücksichtigung der Annahmewahrscheinlichkeit einer Stichprobe.* EMV-Duesseldorf, 2004.

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