TECHNICAL REPORT

CISPR 16-4-3

First edition
2003-11

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

Reference number
CISPR 16-4-3/TR:2003(E)

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

Consolidated editions

The IEC is now publishing consolidated versions of its publications. For example, edition numbers 1.0, 1.1 and 1.2 refer, respectively, to the base publication, the base publication incorporating amendment 1 and the base publication incorporating amendments 1 and 2.

Further information on IEC publications

The technical content of IEC publications is kept under constant review by the IEC, thus ensuring that the content reflects current technology. Information relating to this publication, including its validity, is available in the IEC Catalogue of publications (see below) in addition to new editions, amendments and corrigenda. Information on the subjects under consideration and work in progress undertaken by the technical committee which has prepared this publication, as well as the list of publications issued, is also available from the following:

- **IEC Web Site (www.iec.ch)**

- **Catalogue of IEC publications**

  The on-line catalogue on the IEC web site (www.iec.ch/searchpub) enables you to search by a variety of criteria including text searches, technical committees and date of publication. On-line information is also available on recently issued publications, withdrawn and replaced publications, as well as corrigenda.

- **IEC Just Published**

  This summary of recently issued publications (www.iec.ch/online_news/ justpub) is also available by email. Please contact the Customer Service Centre (see below) for further information.

- **Customer Service Centre**

  If you have any questions regarding this publication or need further assistance, please contact the Customer Service Centre:

  Email: custserv@iec.ch
  Tel: +41 22 919 02 11
  Fax: +41 22 919 03 00

TECHNICAL REPORT

CISPR 16-4-3

First edition
2003-11

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

International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE T

For price, see current catalogue

CONTENTS

FOREWORD 3
INTRODUCTION 5
TABLE RECAPITULATING CROSS-REFERENCES 6
1 Scope 7
2 Normative references 7
3 Definitions 7
4 Recommendation 46/2: Significance of a CISPR limit 10
5 Report 48: Statistical considerations in the determination of limits of radio interference 13
5.1 Introduction 13
5.2 Tests based on the non-central *t*-distribution (sampling by variables) 13
5.3 Tests based on the binomial distribution (sampling by attributes) 17
5.4 Bibliography 18
6 Report 59: An analytical assessment of statistical parameters of radio disturbance in the case of an incompletely defined sample 20
Appendix to Report 59 24

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

This first edition of CISPR 16-4-3, together with CISPR 16-4-1, CISPR 16-4-4 and the second edition of CISPR 16-3, cancels and replaces the first edition of CISPR 16-3, published in 2000, and its amendment 1 (2002). It contains the relevant clauses of CISPR 16-3 without technical changes.

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

A bilingual version of this publication may be issued at a later date.

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.

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

Recommendation 46/1 – p/o CISPR. 11, 1990; Report 48 – p/o CISPR 8B, 1975; Report 59: CIS/A(Sec)58 + CIS/A(Sec)58A, 1983.

INTRODUCTION

CISPR 16-1, CISPR 16-2, CISPR 16-3 and CISPR 16-4 have been reorganised into 14 parts, to accommodate growth and easier maintenance. The new parts have also been renumbered. See the list given below.

Old CISPR 16 publications

CISPR 16-1	Radio disturbance and immunity measuring apparatus
CISPR 16-2	Methods of measurement of disturbances and immunity
CISPR 16-3	Reports and recommendations of CISPR
CISPR 16-4	Uncertainty in EMC measurements

New CISPR 16 publications

CISPR 16-1-1	Measuring apparatus
CISPR 16-1-2	Ancillary equipment – Conducted disturbances
CISPR 16-1-3	Ancillary equipment – Disturbance power
CISPR 16-1-4	Ancillary equipment – Radiated disturbances
CISPR 16-1-5	Antenna calibration test sites for 30 MHz to 1 000 MHz
CISPR 16-2-1	Conducted disturbance measurements
CISPR 16-2-2	Measurement of disturbance power
CISPR 16-2-3	Radiated disturbance measurements
CISPR 16-2-4	Immunity measurements
CISPR 16-3	CISPR technical reports
CISPR 16-4-1	Uncertainties in standardised EMC tests
CISPR 16-4-2	Measurement instrumentation uncertainty
CISPR 16-4-3	Statistical considerations in the determination of EMC compliance of mass-produced products
CISPR 16-4-4	Statistics of complaints and a model for the calculation of limits

More specific information on the relation between the 'old' CISPR 16-3 and the present 'new' CISPR 16-4-3 is given in the table after this introduction (TABLE RECAPITULATING CROSS REFERENCES).

Measurement instrumentation specifications are given in five new parts of CISPR 16-1, while the methods of measurement are covered now in four new parts of CISPR 16-2. Various reports with further information and background on CISPR and radio disturbances in general are given in CISPR 16-3. CISPR 16-4 contains information related to uncertainties, statistics and limit modelling.

CISPR 16-4 consists of the following parts, under the general title *Specification for radio disturbance and immunity measuring apparatus and methods - Uncertainties, statistics and limit modelling*:

- Part 4-1: Uncertainties in standardised EMC tests,
- Part 4-2: Uncertainty in EMC measurements,
- Part 4-3: Statistical considerations in the determination of EMC compliance of mass-produced products,
- Part 4-4: Statistics of complaints and a model for the calculation of limits.

TABLE RECAPITULATING CROSS-REFERENCES

First edition of CISPR 16-3 Clauses, subclauses	First edition of CISPR 16-4-3 Clauses
1.1	1
1.2	2
1.3	3
2.3	4
2.2	5
2.4	6

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 contains recommendations on statistics of disturbance complaints, on the significance of CISPR limits, and specific reports.

Over the years, the CISPR prepared a number of recommendations and reports that have significant technical merit but were not generally available. Reports and recommendations were for some time published in CISPR 7 and 8.

At its meeting in Campinas, Brazil, in 1988, subcommittee A agreed on the table of contents of the first edition of part 3 and to publish the reports for posterity by giving the reports a permanent place in part 3. In 2003, the relevant clauses on statistics were transferred to CISPR 16-4-3.

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 16-1:2003 (all parts), *Specification for radio disturbance and immunity measuring apparatus and methods – Radio disturbance and immunity measuring apparatus*

CISPR 16-2:2003 (all parts), *Specification for radio disturbance and immunity measuring apparatus and methods – Methods of measurement of disturbances and immunity*

CISPR 16-3:2003 *Specification for radio disturbance and immunity measuring apparatus and methods – Part 3: CISPR technical reports*

CISPR 16-4-1:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-1: Uncertainties, statistics and limit modelling – Uncertainties in standardized EMC tests*

CISPR 16-4-2:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics and limit modelling – Measurement instrumentation uncertainties*

CISPR 16-4-4:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-4: Uncertainties, statistics and limit modelling – Statistics of complaints and a model for the calculation of limits*

3 Definitions

For the purpose of this part of CISPR 16, the definitions of CISPR 16-1 and IEV 60050(161) as well as the following definitions apply.

3.1
bandwidth (B_n)
width of the overall selectivity curve of the receiver between two points at a stated attenuation, below the midband response. The bandwidth is represented by the symbol B_n, where n is the stated attenuation in decibels

3.2
impulse bandwidth (B_{imp})

$$B_{imp} = A(t)_{max} \,/\, (2G_o \times IS)$$

where

$A(t)_{max}$ is the peak of the envelope at the IF output of the receiver with an impulse area IS applied at the receiver input;

G_o is the gain of the circuit at the centre frequency.

Specifically, for two critically coupled tuned transformers,

$$B_{imp} = 1{,}05 \times B_6 = 1{,}31 \times B_3$$

where B_6 and B_3 are respectively the bandwidths at the –6 dB and –3 dB points

3.3
impulse area (sometimes called impulse strength) (IS)
the voltage-time area of a pulse defined by the integral:

$$IS = \int_{-\infty}^{+\infty} V(t)\mathrm{d}t \text{ (expressed in µVs or dB(µVs))}$$

NOTE Spectral density (D) is related to impulse area and expressed in µV/MHz or dB(µV)/MHz. For rectangular impulses of pulse duration T at frequencies f <<1/T, the relationship D (µV/MHz) = 2 × 10^6/IS (µVs) applies since D is calibrated in r.m.s. values of a corresponding sine wave.

3.4
electrical charge time constant (T_C)
time needed after the instantaneous application of a constant sine-wave voltage to the stage immediately preceding the input of the detector for the output voltage of the detector to reach 63 % of its final value

NOTE This time constant is determined as follows. A sine-wave signal of constant amplitude and having a frequency equal to the mid-band frequency of the i.f. amplifier is applied to the input of the stage immediately preceding the detector. The indication, D, of an instrument having no inertia (for example, a cathode-ray oscilloscope) connected to a terminal in the d.c. amplifier circuit so as not to affect the behaviour of the detector, is noted. The level of the signal is chosen such that the response of the stages concerned remains within the linear operating range. A sine-wave signal of this level, applied for a limited time only and having a wave train of rectangular envelope is gated such that the deflection registered is 0,63D. The duration of this signal is equal to the charge time of the detector.

3.5
electrical discharge time constant (T_D)
time needed after the instantaneous removal of a constant sine-wave voltage applied to the stage immediately preceding the input of the detector for the output of the detector to fall to 37 % of its initial value

NOTE The method of measurement is analogous to that for the charge time constant, but instead of a signal being applied for a limited time, the signal is interrupted for a definite time. The time taken for the deflection to fall to 0,37D is the discharge time constant of the detector.

3.6
mechanical time constant (T_M) of a critically damped indicating instrument

$$T_M = T_L / 2\pi$$

where T_L is the period of free oscillation of the instrument with all damping removed.

NOTE 1 For a critically damped instrument, the equation of motion of the system may be written as

$$T_M^2(d^2\alpha / dt^2) + 2T_M(d\alpha / dt) + \alpha = ki$$

where

α is the deflection;

i is the current through the instrument;

k is a constant.

It can be deduced from this relation that this time constant is also equal to the duration of a rectangular pulse (of constant amplitude) that produces a deflection equal to 35 % of the steady deflection produced by a continuous current having the same amplitude as that of the rectangular pulse.

NOTE 2 The methods of measurement and adjustment are deduced from one of the following:

a) The period of free oscillation having been adjusted to $2\pi T_M$, damping is added so that α_{TM} = 0,35 α_{max}.

b) When the period of oscillation cannot be measured, the damping is adjusted to be just below critical such that the overswing is not greater than 5 % and the moment of inertia of the movement is such that α_{TM} = 0,35 α_{max}.

3.7
overload factor
ratio of the level that corresponds to the range of practical linear function of a circuit (or a group of circuits) to the level that corresponds to full-scale deflection of the indicating instrument.

The maximum level at which the steady-state response of a circuit (or group of circuits) does not depart by more than 1 dB from ideal linearity defines the range of practical linear function of the circuit (or group of circuits)

3.8
symmetric voltage
in a two-wire circuit, such as a single-phase mains supply, the symmetric voltage is the radio-frequency disturbance voltage appearing between the two wires. This is sometimes called the differential mode voltage. If *Va* is the vector voltage between one of the mains terminals and earth and *Vb* is the vector voltage between the other mains terminal and earth, the symmetric voltage is the vector difference (*Va* – *Vb*)

3.9
asymmetric voltage
radio-frequency disturbance voltage appearing between the electrical mid-point of the mains terminals and earth. It is sometimes called the common-mode voltage and is half the vector sum of *Va* and *Vb*, i.e. (*Va* + *Vb*)/2.

3.10
unsymmetric voltage
amplitude of the vector voltage, *Va* or *Vb* defined in 3.8 and 3.9. This is the voltage measured by the use of an artificial mains V-network

3.11
CISPR indicating range
range specified by the manufacturer which gives the maximum and the minimum meter indications within which the receiver meets the requirements of this part of CISPR 16

4 Recommendation 46/2: Significance of a CISPR limit

(This recommendation replaces Recommendation 46/1, contained in CISPR 7B).

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

The CISPR,

CONSIDERING

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,

RECOMMENDS

that the following interpretation of CISPR limits and of methods of statistical sampling for compliance of mass-produced appliances with these limits should be adopted:

1 a CISPR limit is a limit which 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;

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;

3 type tests can be made;

3.1 on a sample of appliances of the type with statistical evaluation in accordance with clause 5 below;

3.2 for simplicity, on one item only (see clause 4);

4 subsequent tests from time to time on items are taken at random from the production are necessary especially in 3.2 above;

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 3.1 above;

5 that statistically assessed compliance with limits shall be made according to one of the two tests described below or to some other test which ensures compliance with the requirements of clause 2;

5.1 test based on the non-central *t*-distribution. This test should be performed on 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:

$$\bar{x}_n + kS_n \le L$$

where

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

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

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:

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);

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

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 should the test on the sample result in non-compliance with the requirements in 5.1 or 5.2, then a second sample may be tested and the results combined with those from the first sample and compliance checked for the larger sample.

6 Immunity tests

6.1 Application of the CISPR 80 %/80 % rule to immunity tests

In the assessment of the immunity of appliances and equipment in large-scale production, consideration should be given to the specification of the statistical method to be used in the CISPR sampling scheme. Two methods have been standardized: one using the binomial distribution and the other using the non-central *t*-distribution.

The binomial distribution method is essentially sampling by attributes. Hence, this method should be used in an immunity test in which the immunity level cannot be determined, with the result that it is only possible to verify whether an appliance or equipment complies with the immunity limit or not, i.e. only a pass or fail test at a specified immunity level is possible.

The non-central *t*-distribution method is essentially sampling by variables. Hence, this method is suitable for an immunity test in which the immunity level or the level of a signal that is a measure of the degradation of operation, can be determined. The latter level shall be expressed in logarithmic units before applying the non-central *t*-distribution method.

6.2 Application guidelines

Subclause 6.1 only gives conditions related to the choice of statistical test method to be used in the assessment of the immunity of appliances and equipment in large-scale production after it has been decided by the relevant Product Committee that a statistical evaluation is needed. A Product Committee may also decide that a type-test alone is adequate.

In the formulation of 6.1, use has been made of the IEC definitions of immunity level, immunity limit and degradation, which read

– the *immunity level* is the maximum level of a given electromagnetic disturbance, incident in a specified way on a particular device, equipment or system, at which no degradation of operation occurs;

– the *immunity limit* is the minimum required immunity level;

– *degradation* is an undesired departure in the operational performance of any device, equipment or system from its intended performance.

6.2.1 Sampling by attributes

When testing the immunity of an equipment under test (EUT), the combination of type of disturbance signal and type of susceptible part in the EUT might result in damage to the EUT if the immunity level is exceeded. In such a case, only an immunity test on Pass/Fail or (Go/No Go) basis will be possible, i.e. a test which verifies only whether the EUT complies or does not comply with the immunity limit. Consequently, only two test results are possible: the EUT passes or the EUT fails. The properties "pass" and "fail" are attributes of the EUT, so the method based on the binomial distribution has to be used.

An immunity test on a Pass/Fail basis is not necessarily associated with damage to the EUT. If the test is to be carried out with a fixed-level electromagnetic disturbance, it may also be possible to use only the Pass/Fail criterion. Also in this case the sampling method based on the binomial distribution has to be used.

An example of an immunity test on Pass/Fail basis in view of the possibility of damaging the EUT is the testing of telecommunication equipment for immunity to transients caused by lightning. An example of such a test in view of the fixed-level disturbance is the electroacoustic discharge test on (digital) information technology equipment.

6.2.2 Sampling by variables

If the EUT and the chosen immunity test allow the determination of the immunity level or the level of a signal that is a measure of the degradation of operation, these levels will be variables and, hence, a Product Committee may decide to opt for sampling by variables. In that case, the sampling method based on the non-central *t*-distribution has to be used.

Note the above formulation "may decide", as a Product Committee can always decide to opt for a test on a Pass/Fail basis. In addition, note that if the EUT is sufficiently immune, it might not be possible to determine the levels mentioned. This does not exclude, however, the possibility of sampling by variables. Such a situation is completely comparable with the situation in an emission test when the emission level is lower than the noise level of the CISPR receiver.

The determination of the immunity level in an immunity test is, generally speaking, not very practical. It always causes over-exposure of the EUT to the applied disturbance signal, and may easily lead to unforeseen effects during immunity testing. Nevertheless, there is no need to exclude this determination beforehand.

A signal which is a measure of the degradation of operation of the EUT may be available for sampling by variables: for example, the demodulated signal when testing several samples of EUT, say an audio equipment, for their immunity to amplitude-modulated RF signals of constant level and frequency. The level of the demodulated signal is then a measure of the degradation of the EUT. Another example is the bit-error rate when performing immunity tests on digital communication equipment.

5 Report 48: Statistical considerations in the determination of limits of radio interference

(Identical with the text taken from CISPR 8B).

5.1 Introduction

Compliance of mass-produced appliances with radio interference limits should be based on the application of statistical techniques that have to ensure the consumer with an 80 % degree of confidence that 80 % of the appliances of a type being investigated are below the specified radio interference limit. This so-called 80 %/80 % rule protects the consumer from appliances with too high a radio interference level, 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. The manufacturer knows only that if 20 % of the items of the batch are above the relevant limit, the acceptance probability is 20 % and knowledge is necessary about the dependence of the acceptance probability on the sample size and the fraction items of the batch that are above the relevant limit. The curves representing the acceptance probability versus fraction items above the limit and the sample size as a parameter, are called the operating characteristic curves. These curves can be calculated using either the non-central *t*-distribution (sampling by variables) or the binomial distribution (sampling by attributes).

The Poisson distribution cannot be used since the fraction appliances above the limit should be very small (<1 %) and the sample size large (more than 20 items). Besides sampling of batches, it is also possible to ensure conformity of the production by means of control chart techniques. These methods provide a continuous recording of the wanted information – for example, the radio interference level of the appliances being produced.

5.2 Tests based on the non-central *t*-distribution (sampling by variables)

The following condition must be fulfilled:

$$\bar{X} + \mathrm{k}\, S_{\mathrm{n}} \le L$$

and has to ensure, with an 80 % degree of confidence, that 80 % of the appliances produced on a large scale are below a specified radio interference limit L.

Meaning of the symbols used in this expression:

$\bar{X}$ = mean value of the interference level of the sample with size n of the appliances to be tested; $\bar{X}$ is known;

S_{n} = standard deviation of the interference level of the sample with size n of the appliances to be tested; S_{n} is known;

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_{\mathrm{i}} \qquad\qquad S_{\mathrm{n}} = \sqrt{\frac{\sum \left(X_{\mathrm{i}} - \bar{X}\right)^2}{n-1}}$$

k = constant to be determined in such a way that the above-stated rule is satisfied;

L = the permissible radio interference limit; L is an upper limit.

5.2.1 Determination of the constant k

It is assumed that the production being investigated has a normal distribution with the following parameters:

μ = mean value of the radio interference level of all appliances; μ is unknown;

σ = standard deviation of the radio interference level of all appliances; σ is unknown.

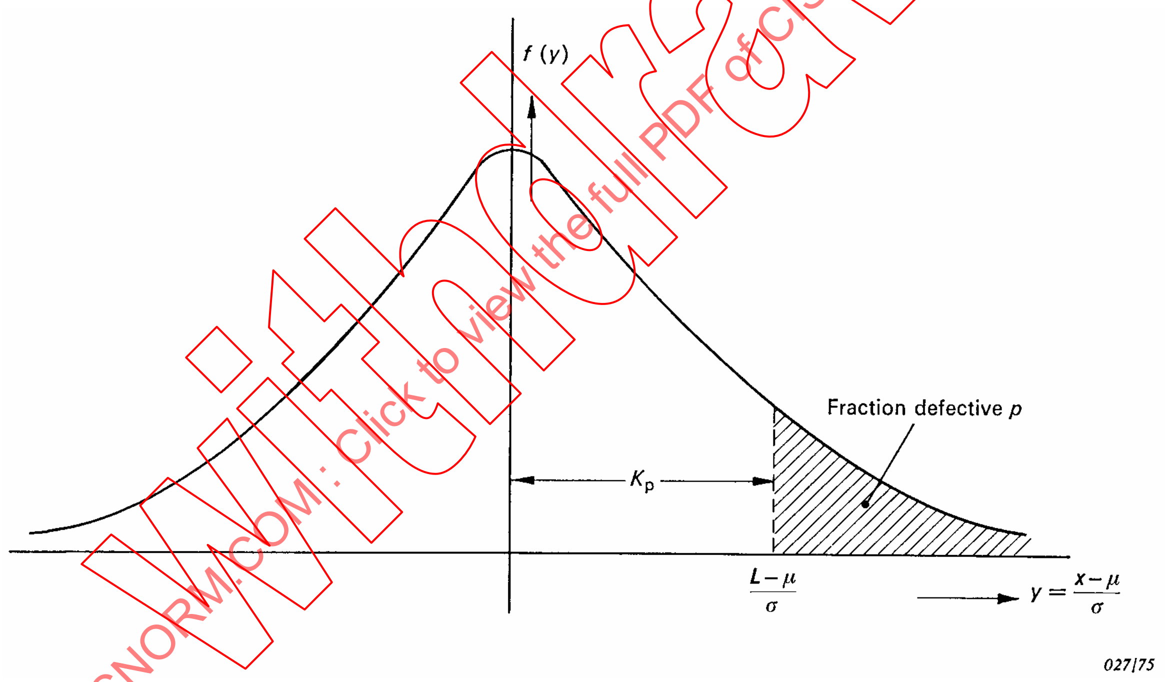
Assume: p fraction that is above the limit L (fraction defective) and $(1 - p)$ fraction of the lot below the specified limit L.

Define a constant K_p:

$$p = \int_{K_p}^{\infty} \frac{1}{\sqrt{2\pi}} e^{-\frac{y^2}{2}} dy$$

in which $f(y) = \frac{1}{\sqrt{2\pi}} e^{-\frac{y^2}{2}}$ is the standardized normal density function.

K_p can be determined from appropriate tables of the normal distribution function.



From the definition of K_p as well as the figure drawn above it follows that:

$$L = \mu + K_p\sigma \qquad K_p > 0$$

since L is an upper limit.

According to the CISPR, p = 0,2, then K_p = 0,84. The test instruction can now be read as follows:

$$p\left(\overline{X} + kS_n \geq L \,/\, L = \mu + K_p\sigma\right) = 1 - \alpha$$

The probability α of a batch with a fraction defective p being accepted gives the *consumer's risk.*

For CISPR, α = 0,2 (1 – α = 0,8 → 80 %) and K_p = 0,84.

To determine the constant k, the expression should be rewritten as follows:

$$p\left(\overline{X} + \mathrm{k}S_n \geq L \,/\, L = \mu + K_p\sigma\right) = 1 - \alpha$$

$$= p\left(\frac{\overline{X}-\mu}{\sigma/\sqrt{n}} - \frac{L-\mu}{\sigma/\sqrt{n}} \geq -\frac{\mathrm{k}S_n}{\sigma/\sqrt{n}} \Bigg/ L = \mu + K_p\sigma\right)$$

$$= p\left(\frac{-\dfrac{\overline{X}-\mu}{\sigma/\sqrt{n}} + \dfrac{L-\mu}{\sigma/\sqrt{n}}}{S_n/\sigma} \leq \mathrm{k}\sqrt{n} \Bigg/ L = \mu + K_p\sigma\right)$$

By definition:

$$t_{\mathrm{n.c.}} = \frac{-\dfrac{\overline{X}-\mu}{\sigma/\sqrt{n}} + \dfrac{L-\mu}{\sigma/\sqrt{n}}}{S_n/\sigma}$$

$t_{\mathrm{n.c.}}$ is a non-central *t*-distribution with non-centrality parameter

$$(L-\mu)/\sigma/\sqrt{n} = K_p\sqrt{n}$$

and (n – 1) degrees of freedom.

The non-centrality parameter follows from the condition that not more than a fraction p of the lot being investigated is above the permissible limit.

$$p\left(t_{\mathrm{n.c.}} \leq \mathrm{k}\sqrt{n}\right) = 1 - \alpha$$

$$p\left(\frac{t_{\mathrm{n.c.}}}{\sqrt{n-1}} \leq \mathrm{k}\sqrt{\frac{n}{n-1}}\right) = 1 - \alpha$$

This probability function has been tabulated in [1] and [2]. Some figures are given below.

With α = 0,2, p = 0,1 (1 – α = 80 %, 1 – p = 80 %), the following values for k will be obtained for different sample sizes:

n	4	5	6	7	8	9	10	11	12
k	1,68	1,51	1,42	1,35	1,30	1,27	1,24	1,21	1,20

5.2.2 Determination of the sample size *n*

The producer wants to know the probability of the appliances being accepted and has to know:

$$p\left(\overline{X} + kS_n \le L / L = \mu + K_p \sigma\right)$$

By definition, this expression is equal to $\beta(p)$, the acceptance probability. The probability $1 - \beta(p)$ of a batch with a fraction defective p being rejected gives the *producer's risk*.

This can be rewritten as follows:

$$p\left(\frac{t_{n.c.}}{\sqrt{n-1}} \ge k\sqrt{\frac{n}{n-1}}\right) = \beta(p)$$

For a lot with the same fraction defective p as in clause 1, $\beta(p)$ equals α. With $p = 0{,}2$, $\alpha = 0{,}2$ (CISPR values) $\beta(0{,}2)$ is 0,2. From the producer's point of view, $\beta(p)$ should be maximized by improving the production (a smaller percentage of defective) since $\beta(p)$ depends on the defective fraction.

Generally the manufacturer needs an acceptance probability as high as 95 %. The function representing the dependence of the acceptable probability $\beta(p)$ on the fraction defective p is called the operating characteristic if the test and $1 - \beta(p)$ the power curve of the test. The mathematical representation for the O.C. curve:

$$\beta(p) = p\left(\frac{t_{n.c.}}{\sqrt{n-1}} \ge k\sqrt{\frac{n}{n-1}}\right)$$

for fixed *n*.

In Graph 1, a few curves are given for $\alpha = 0{,}2$. From these curves it can be seen that in order to ensure the same acceptance probability $\beta(p)$, the percentage of defectives will increase with the sample size. The so-called discriminatory power of the operating characteristic curve increases as the sample size increases and is ideal if *n* equals the total number of appliances to be approved.

5.2.3 Example (see Graph 1)

A batch of appliances has to be checked according to the 80 %/80 % rule with a sample size $n = 6$, we have k = 1,42. The consumer has an 80 % degree of confidence that 80 % of the batch lies below the limit.

The acceptance probability $\beta(p)$ is 20 % at $p = 0{,}2$ (80 % below the limit). To obtain a greater acceptance probability, the percentage defective p should be decreased. At $p = 0{,}035$ (96,5 % below the limit), the acceptance probability is 80 %. From each 10 samples consisting of six units taken from lots with $p = 0{,}035$, eight samples will on average yield a positive result. At $p = 0{,}009$ (99,1 % below the limit), the acceptance probability is 95 %. In the latter case, the manufacturer has to apply a μ and σ which fulfil the expression $\mu + 2{,}4\,\sigma \le L$.

5.3 Tests based on the binomial distribution (sampling by attributes)

The number of defective units *c* that occur in a sample of size *n* has to ensure with an 80 % degree of confidence that 80 % of the appliances produced on a large scale are below a specified radio interference limit *L*. An item has to be considered defective as soon as its radio interference level is above the specified value *L*.

5.3.1 Determination of constant *c*

The occurrence of defective units by sampling a batch of appliances should satisfy the requirement that the occurrences are statistically independent and not more than one occurrence takes place at the same moment.

The binomial distribution is characterized by the fraction defective *p* of the batch of appliances being tested and the sample size *n*.

The probability that a sample of size *n* has exactly *c* defective items is given by:

$$p(x = c) = \binom{n}{c} p^c (1 - p)^{n-c} \qquad n, c \text{ integers}$$

and that this sample contains *c* defective items or less by:

$$p(x \le c) = \sum_{x=0}^{c} \binom{n}{x} p^x (1 - p)^{n-x} \qquad n, x, c \text{ integers}$$

$p\,(x \le c)$ represents the distribution function.

The probability that a sample with size *n* contains more than *c* defective items should be $(1 - \alpha)$ if the batch of appliances being tested has the maximum allowed fraction defective, hence:

$$p(x \le c \,/\, p) = 1 - \alpha$$

$$p(x \le c \,/\, p) = \sum_{x=0}^{c} \binom{n}{x} p^x (1 - p)^{n-x} = \alpha$$

According to the CISPR requirements: α = 0,2 and *p* = 0,2. The corresponding *c* and *n* values are given in the left-hand table. The right-hand table represents the values for *c* and *n* if α = 0,05 and *p* = 0,2. *c* represents the allowed number of defective items and *n* the sample size.

c	*n*
0	7
1	14
2	20
3	26
4	32
5	38
for a consumer's risk of 20 %	

c	*n*
0	13
1	22
2	29
3	36
4	43
5	50
for a consumer's risk of 5 %	

To have an 80 % degree of confidence that 80 % of the appliances are below the limit *c* and *n* should correspond with the values listed in the left-hand table.

5.3.2 Determination of sample size *n*

Analogue to 5.2.2, the acceptance probability follows from:

$$p(x \leq c \,/\, p) = \beta(p)$$

If p = 0,2 then β(0,2) = α = 0,2. The probability 1 – β(0,2) of the batch of appliances being rejected is 0,8.

The operating characteristic curve is given by

$$\beta(p) = \sum_{x=0}^{c} \binom{n}{x} p^{x} (1-p)^{n-x}$$

Curves have been drawn in graph 2.

5.3.3 Control charts

The use of control charts (3) provides information about the influence of the production process on the values to be statistically controlled and indicates the deviations from the original values. In this way, an insight can be gained into the performance of the production process.

Generally the sample average $\overline{X}$ and the sample standard deviation S_n give a good estimation of the quality characteristics to be studied. For mass-produced appliances, a sufficient number of samples can be taken to ensure conformity of $\overline{X}$ and S_n with the required mean value μ and standard deviation σ. The confidence intervals for various fractions of the production may be predicted from these values.

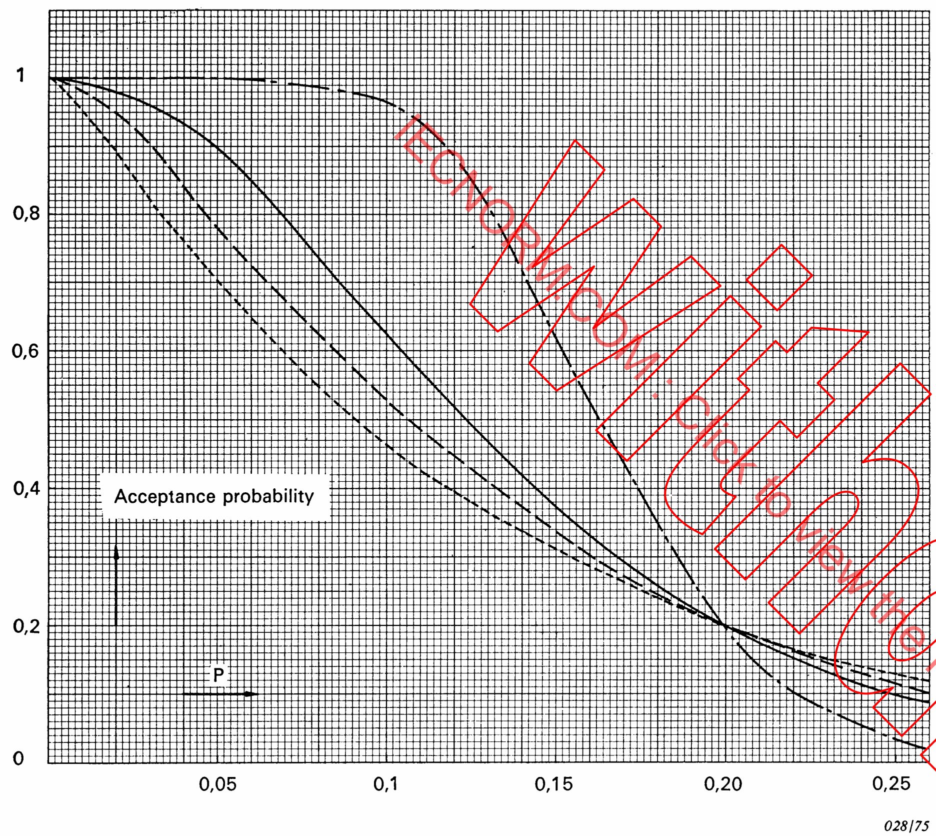
Control chart techniques can easily be applied in such a way that the consumer has the required 80 % confidence that 80 % of the production is below the permissible limit, whereas at the same time the use of small samples is avoided.

5.4 Bibliography

[1] *Tables of the non-central t-distribution*, Resnikoff, G.J., and Lieberman, G.J., Stanford University, California, 1957.

[2] CISPR/WG 8 (Groenveld/Neth.)1, March 1972.

[3] *Statistics and Experimental Design I*, pp 298-348, Johnson, N.L., and Leone, F.C., Wiley and Sons, New York, 1964.



Graph 1

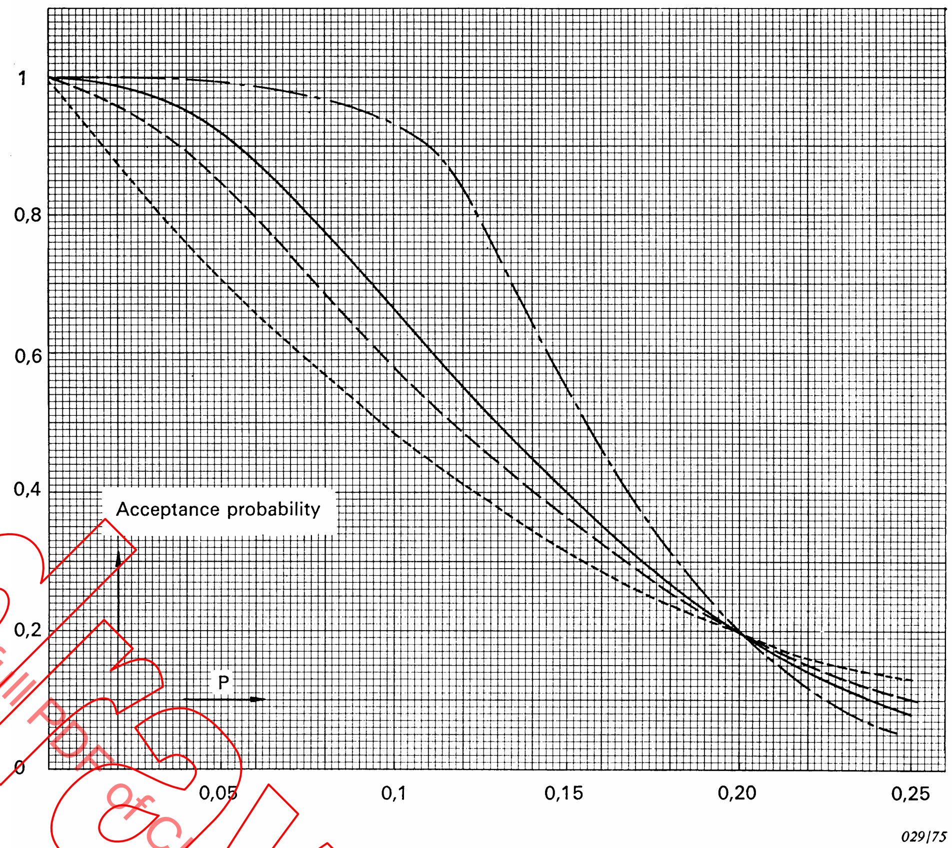
Operating characteristic curves for non-central *t*-distribution

$n = 6$; $k = 1{,}42$

$n = 8$; $k = 1{,}30$

$n = 12$; $k = 1{,}20$

$n = 51$; $k = 0{,}99$



Graph 2

Operating characteristic curves for binomial distribution

$n = 7$; $k = 0$

$n = 14$; $k = 1$

$n = 20$; $k = 2$

$n = 49$; $k = 7$

6 Report 59: An analytical assessment of statistical parameters of radio disturbance in the case of an incompletely defined sample

CISPR Recommendation 46/2 specifies the requirements for the statistical assessment of series-produced equipment. The assessment is based on the non-central *t*-distribution and it requires that the actual levels of the radio *disturbance* generated by each equipment in a sample is measured. The assessment of acceptability is then made during the mean and the standard deviation of the radio *disturbance* levels measured.

In a number of cases, it may not be possible to measure the levels of radio *disturbance* generated by all the *units of* the equipment in the sample because of insufficient sensitivity of the testing apparatus used. In such cases the available distribution of the values of radio *disturbance* levels (expressed in decibels) is truncated from below, giving a one-sided and incomplete determination of the distribution.

Figure 1 shows the probability density function $\varphi(\gamma,\gamma_0)$ of a normal distribution of radio *disturbance* values truncated from below.

Figure 2 shows the function $\Phi(\gamma,\gamma_0)$, which is an alternative illustration of the same truncated distribution.

This report presents the analytical method of assessment of mathematical expectation and standard deviation of radio *disturbance* values distributed according to a normal law, on the basis of the known parameters of truncated distribution and the degree of truncation.

Assume that for the determination of the statistical parameters of the distribution of radio *disturbance* values one takes a sample of *n units* from the parent population which is a normal distribution $N(\mu x;\sigma)$. In this sample $n_0 < n$ *units* have a radio disturbance level $X < X_L$, where X_L is the limit of sensitivity of the measuring apparatus, this limit being the point of truncation. Hence, in a sample of the size *n* there are only $n - n_0$ *units* with radio *disturbance* values which are greater than X_L, and for these units only can the radio *disturbance* levels be measured. It is possible to consider $n - n_0$ of radio *disturbance* values as the measurements from truncated distribution with the truncation degree $\Phi(\gamma_0)$. The ratio n_0/n is the assessment of the degree or truncation $\Phi(\gamma_0)$.

The average $\overline{X}$ and the standard deviation *S* of the measured radio d*isturbance* values are an estimation of the parameters μ_x and σ in the parent population of the equipment. $\overline{X}$ and *S* are determined from the expressions:

$$\overline{X} = \overline{X}_y - \frac{S_y}{\left(\frac{1-\Phi(\gamma_0)}{\varphi(\gamma_0)}\left(\frac{1-\Phi(\gamma_0)}{\varphi(\gamma_0)}+\gamma_0\right)-1\right)^{1/2}} \tag{1}$$

$$S = \frac{S_y}{\left(\frac{\varphi(\gamma_0)}{1-\Phi(\gamma_0)}\left(\gamma_0-\frac{\varphi(\gamma_0)}{1-\Phi(\gamma_0)}\right)+1\right)^{1/2}} \tag{2}$$

where

$\gamma_0 = (X_L - \mu)/\sigma$ is a specified truncation point;

$\Phi(\gamma_0)$ is a value of the normal distribution function

$$\Phi(\gamma) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\gamma} e^{-\frac{x^2}{2}} dx$$

$\varphi(\gamma_0)$ is a value of a probability density function of a normal distribution

$$\varphi(\gamma) = \frac{1}{\sqrt{2\pi}} e^{-\frac{\gamma^2}{2}}$$

The values of the sampling parameters $\overline{X}_y$ and S_y of the truncated distribution included in the formulas (1) and (2) are determined from the following expressions:

$$\overline{X}_y = \frac{1}{n - n_0} \sum_{i=1}^{n-n_0} X_i \qquad (3)$$

$$S_y = \left(\frac{1}{n - n_0 - 1} \sum_{i=1}^{n-n_0} \left(X - \overline{X}_y \right)^2 \right)^{1/2} \qquad (4)$$

The mathematical expectation and standard deviation of a radio disturbance value in the parent population of equipment, which has normal distribution, are determined from the parameters of an incompletely determined sample in the following succession:

a) the radio disturbance values produced by all the units of the sample of the size n are measured;

b) the degree of truncation $\Phi(\gamma_0) = \dfrac{n_0}{n}$ is determined;

c) the values of the specified point of truncation γ_0 are determined from the tables of a function of the normal distribution on the basis of the known values of $\Phi(\gamma_0)$;

d) from the tables of a probability density function of normal distribution the values of $\varphi(\gamma_0)$ are found;

e) the values of the statistical parameters of the truncated distribution of measured disturbance produced by the articles of a sample of the size $n - n_0$ are determined from formulae (3) and (4);

f) the values of the statistical parameters of the complete distribution of disturbance levels from the sample of equipment of size n are determined from formulae (1) and (2).

NOTE An example calculation is given in the appendix.

The confidence interval of the parameter $\overline{X}$ with the confidence $1 - \alpha$ is determined by the expression:

$$\overline{X} - U_p S \sqrt{\frac{\mu_x \gamma_0}{n}} < \mu_x < \overline{X} + U_p S \sqrt{\frac{\mu_x \gamma_0}{n}}$$

where

$U_p = U_{1-\frac{\alpha}{2}}$ is a quartile of distribution N(0.1);

$\mu_x(\gamma_0)$ is a function of truncation degree determined from table 1.

Table 1 (relative to Recommendation 46/2)

γ_0	–3,0	–2,5	–2,1	–2,0	–1,9	–1,8	–1,7	–1,6	–1,5	–1,4
$\mu_x(\gamma_0)$	1,000	1,001	1,002	1,003	1,004	1,005	1,006	1,009	1,011	1,015
γ_0	–1,3	–1,2	–1,1	–1,0	–0,9	–0,8	–0,7	–0,6	–0,5	–0,4
$\mu_x(\gamma_0)$	1,019	1,025	1,032	1,042	1,054	1,069	1,089	1,114	1,147	1,189
γ_0	–0,3	–0,2	–0,1	0	0,1	0,2	0,3	0,4	0,5	0,6
$\mu_x(\gamma_0)$	1,243	1,312	1,401	1,517	1,667	1,863	2,118	2,453	2,893	3,473
γ_0	0,7	0,8	0,9	1,0	1,1	1,2	1,3	1,4	1,5	1,6
$\mu_x(\gamma_0)$	4,241	5,261	6,623	8,448	10,90	14,22	18,73	24,89	33,34	44,99
γ_0	1,7	1,8	1,9	2,0						
$\mu_x(\gamma_0)$	61,13	83,64	115,2	159,7						

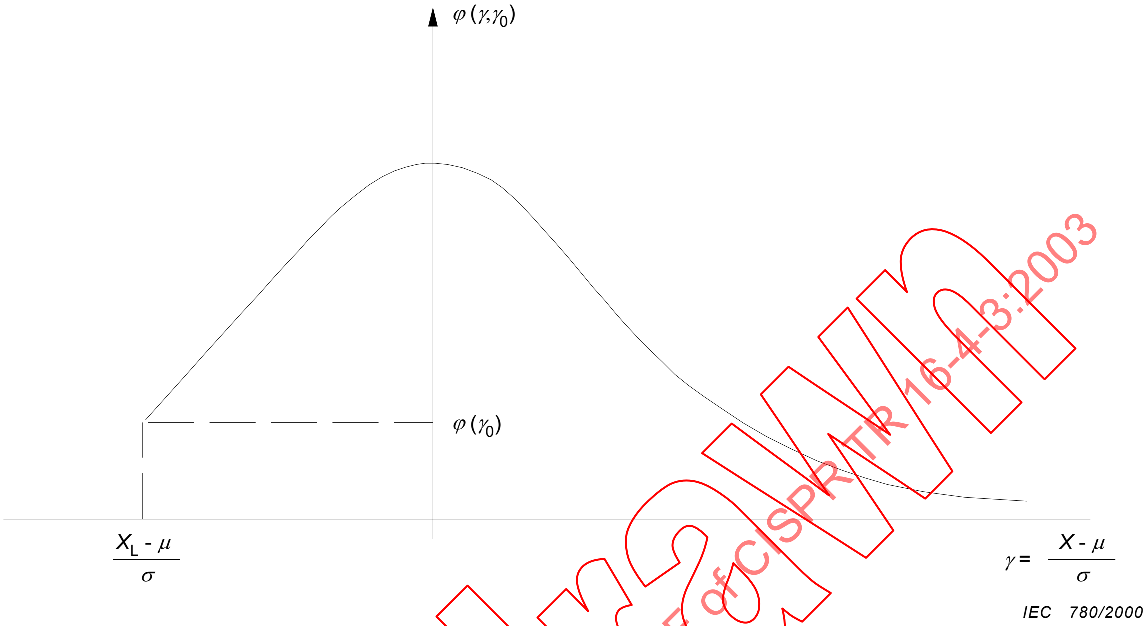


Figure 1 – The probability density function $\varphi(\gamma;\gamma_0)$

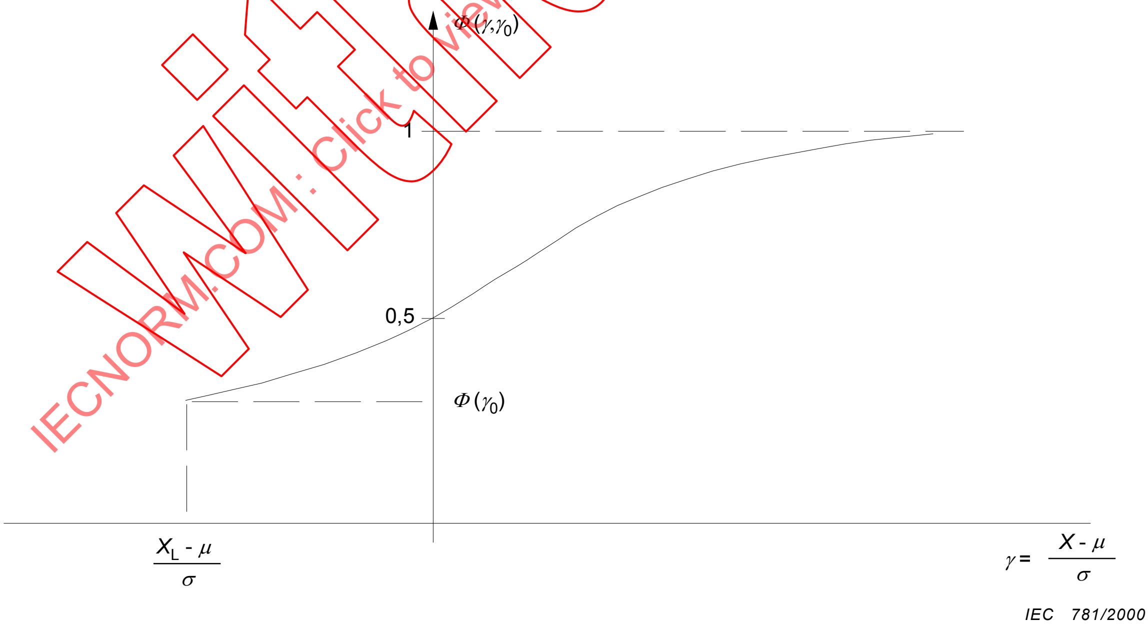


Figure 2 – The truncated distribution function $\Phi(\gamma;\gamma_0)$