BRITISH STANDARD

BS CISPR 16-3:2000

Specification for radio disturbance and immunity measuring apparatus and methods —

Part 3: Reports and recommendations of CISPR

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The UK participation in its preparation was entrusted by Technical Committee GEL/210, Electromagnetic Compatibility, to Subcommittee GEL/210/12, EMC - Basic and Generic Standards, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

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Summary of pages

This document comprises a front cover, an inside front cover, the CISPR title page, pages 2 to 239 and a back cover.

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TECHNICAL REPORT

CISPR 16-3

First edition
2000-05

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Specification for radio disturbance and immunity measuring apparatus and methods –

Part 3: Reports and recommendations of CISPR

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

Partie 3: Rapports et recommandations du CISPR

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CONTENTS

Page

FOREWORD 3

Clause

1 General 5
1.1 Scope 5
1.2 Reference documents 5
1.3 Definitions 5
2 Statistics 8
2.1 Recommendation 2/3: Statistics of complaints and sources of interference (this recommendation replaces Recommendation 2/2 in CISPR 7B) 8
2.2 Report 48: Statistical considerations in the determination of limits of radio interference (identical with the text taken from CISPR 8B) 17
2.3 Recommendation 46/2: Significance of a CISPR limit (this recommendation replaces Recommendation 46/1, contained in CISPR 7B) 24
2.4 Report 59: An analytical assessment of statistical parameters of radio disturbance in the case of an incompletely defined sample 27
3 A model for the calculation of limits 33
3.1 Introduction 33
3.2 Probability of interference 33
3.3 Circumstances of interferences 35
3.4 Basic model 43
3.5 Application of the basic model 44
3.6 An alternative method used for ISM equipment 47
4 Technical reports 55
4.1 Correlation between measurements made with apparatus having characteristics differing from the CISPR characteristics and measurements made with CISPR apparatus 55
4.2 Interference simulators 61
4.3 Relationship between limits for open-area test site and the reverberating chamber 67
4.4 Characterization and classification of the asymmetrical disturbance source induced in telephone subscriber lines by AM broadcasting transmitters in the LW, MW and SW bands 72
4.5 The predictability of radiation in vertical directions at frequencies above 30 MHz 105
4.6 The predictability of radiation in vertical directions at frequencies up to 30 MHz 162
4.7 Parameters of broadband antennas 231
5 Background and history 234
5.1 The history of the CISPR 234
5.2 Historical background to the method of measurement of the interference power produced by electrical household and similar appliances in the VHF range 237

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Full document details: BS CISPR 16-3:2000

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 3: Reports and recommendations of CISPR

FOREWORD

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2) The formal decisions or agreements of the 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 National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
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Technical reports do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

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

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
CISPR/A/CO/67 CISPR/A/CO/77	CISPR/A(CO)82 CISPR/A(CO)84

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

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

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This document which is purely informative is not to be regarded as an International Standard.

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

Recommendation 2/2 – p/o CISPR. 7B, 1975; Recommendation 46/1 – p/o CISPR. 11, 1990; Report 33 – p/o CISPR 8, 1969; Report 38 – p/o CISPR 8, 1969; Report 48 – p/o CISPR 8B, 1975; Report 49 – p/o CISPR 8C, 1980; Report 61 = CISPR 23, 1987; Report 59: CIS/A(Sec)58 + CIS/A(Sec)58A, 1983; Report: CIS/A(Sec)67 + CIS/A(Sweden)29; RM 2828/CISPR/A, 1985; CIS/A(CO)32, 1985; CIS/A(Sec)58, 1983; CIS/A(Sec)58A, 1983; CIS/A(Sec)67, 1985; CIS/A(CO)67, 1992; CIS/A(CO)67A, 1993; CIS/A(CO)77A, 1993; CIS/A(CO)81, 1987; CIS/A(CO)82, 1994; CIS/A(CO)84, 1994; CIS/A(Sec)84, 1987; CIS/A(Sec)88, 1988; CIS/A(Sec)88A, 1988; CIS/A(Sec)94, 1989; CIS/A(Sec)115, 1991; CIS/A(Sec)115A, 1991; CIS/A(Sec)116, 1991; CIS/A(Sec)124, 1991; CIS/A(Sec)128, 1992; CIS/A(Sec)132, 1993; CIS/A/166/CD, 1995.

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

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SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 3: Reports and recommendations of CISPR

1 General

1.1 Scope

This part of CISPR 16 contains recommendations on statistics of disturbance complaints, on the significance of CISPR limits, on determination of CISPR limits and other 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 part 3 and to publish the reports for posterity by giving the reports a permanent place in part 3.

1.2 Reference documents

IEC 60083:1997, *Plugs and socket-outlets for domestic and similar general use standardized in member countries of IEC*

IEC 60364-4, *Electrical installations of buildings – Part 4: Protection for safety*

CISPR 11:1997, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*

CISPR 13:1996, *Limits and methods of measurement of radio interference characteristics of sound and television broadcast receivers and associated equipment*

CISPR 14-1, *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission*

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

CISPR 16-2:1996, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2: Methods of measurement of disturbances and immunity*

ITU-R BS 468-4, *Measurement of audio-frequency noise voltage level in sound broadcasting*

1.3 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.

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1.3.1
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

1.3.2
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 (see 1.3-A.2 in annex 1.3-A for further information)

1.3.3
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) = $2 \times 10^6/IS$ (µVs) applies since D is calibrated in r.m.s. values of a corresponding sine wave.

1.3.4
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.

1.3.5
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.

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1.3.6
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 $\alpha_{TM} = 0{,}35\ \alpha_{max}$.

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 $\alpha_{TM} = 0{,}35\ \alpha_{max}$.

1.3.7
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)

1.3.8
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*)

1.3.9
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.

1.3.10
unsymmetric voltage
amplitude of the vector voltage, *Va* or *Vb* defined in 1.3.8 and 1.3.9. This is the voltage measured by the use of an artificial mains V-network

1.3.11
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

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2 Statistics

2.1 Recommendation 2/3: Statistics of complaints and sources of interference (this recommendation replaces Recommendation 2/2 in CISPR 7B)

The CISPR,

CONSIDERING

a) that many administrations regularly publish statistics on interference complaints;

b) that it would be useful to be able to compare the figures for certain categories;

c) that, at present, varied and ambiguous presentation often renders this comparison difficult,

RECOMMENDS

1 that the statistics supplied by National Committees should be in such a form that the following information may be readily extracted:

1.1 number of complaints as a percentage of the total number of receiving licences for television, sound broadcasting and other services;

1.2 the relative aggressivity of the various sources of interference in the different frequency bands;

1.3 the comparison of the interference caused by the same source in different frequency bands;

1.4 the effectiveness of limits (CISPR or national) and other counter-measures on subclauses 1.1, 1.2 and 1.3;

2 that the terms used in publication of statistics as recommended in clause 3 should have the following meaning:

2.1 *complaint:* a request for assistance made to the interference service by a listener or a viewer who complains that his reception is degraded by interference. For the purpose of these statistics, one complaint will be recorded for each frequency band for which a confirmed complaint has been received;

2.2 *source:* a source of interference is the apparatus or installation which causes interference. Interference may be caused by a group of devices, for example, a number of fluorescent lamps on one circuit. In such cases, the number to be entered in the statistics is determined by the interference service;

NOTE To facilitate comparison of statistics, the method used to determine the number of sources should be stated.

one source may cause many complaints and one complaint may be caused by more than one source. Therefore, it is clear that the number of sources and the number of complaints against any classification code may not be related;

for the purpose of these statistics, both active generators of electrical energy and apparatus and installations which cause interference by secondary effects (secondary modulation) are included. See also Appendix II for a complete list;

2.3 *cause of complaint other than a source:* a reason for unsatisfactory reception in a case in which no source is concerned. See also Appendix II for a complete list;

3 that statistics should cover a complete calendar year; they should whenever possible be presented in the following form, without necessarily employing the finer categories listed in Appendix II. It s not intended to exclude further subdivisions; these are desirable, but they should fit into the scheme of the standard form;

the code numbers refer to the items listed in Appendices I and II;

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Statistics of interference complaints

Source of interference or other cause of complaint						Number of complaints per service from each source					
Classification code				Description	Total number in each classification	Broadcasting [a]					Other services [b]
						Sound [c]		Television [c]			
						LF/ MF/ HF	II	I	III	IV/V	
A	1	1									
	2	1									
		etc. as in the appendices									
					Totals						

[a] LF = low frequency (long waves);
MF = medium frequency (medium waves);
HF = high frequency (short waves).
These three bands may either be grouped together, as shown, or dealt with separately.
II = Band II (VHF/FM)
I = Band I (VHF/television)
III = Band III (VHF/television);
IV/V = Band IV/V (UHF/television).

[b] The service and band affected should be stated.

[c] At the time of receipt of complaints of interference, i.e. before they have been investigated fully, it may not be possible to apportion the complaints accurately to the various broadcasting services. If this is so, then the number of complaints should be stated separately for sound broadcasting and television.

Appendix I to Recommendation 2/3: Classification of sources of interference and other causes of complaint

Main categories

Classification code	Description of the source
A	Industrial scientific and medical RF apparatus
A.1	Industrial and scientific RF apparatus
A.1.1	Apparatus tuned to free radiation frequency
A.1.2	Apparatus not tuned to free radiation frequencies
A.2	Medical radio-frequency apparatus
A.2.1	Apparatus tuned to free radiation frequencies
A.2.2	Apparatus not tuned to free radiation frequencies
A.3	Sparking apparatus (except ignition)
B	Electric power supply, distribution and traction
B.1	AC voltages exceeding 100 kV
B.1.1	Power lines overhead
B.1.2	Generating and switching stations
B.2	DC voltages exceeding 100 kV
B.2.1	Power lines overhead
B.2.2	Converting stations

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Classification code	Description of the source
B.3	Voltages 100 kV to 1 kV (subdivision as for B.1)*
B.4	Voltages 1 kV to 450 kV (subdivision as for B.1)*
B.5	Low tension power supply and distribution (<450 V)
B.5.1	Power lines overhead
B.5.2	Generating and switching stations
B.6	Electric traction
B.6.1	Railways
B.6.2	Tramways
B.6.3	Trolley buses
C	Electricity consumers' equipment (industrial and similar)
C.1	Generators
C.2	Motors (P > 700 W)
C.2.1	Rated power P: 700 W < P ≤ 1 000 W
C.2.2	Rated power P: 1 000 W < P ≤ 2 000 W
C.2.3	Rated power P: 2 000 W < P
C.3	Contacts
C.4	Ignition
C.5	Rectifiers
C.6	Convertors
C.7	Diode thyristor and thyratron control equipment
C.8	Cattle fences
D	Low-power appliances as normally used in households, offices and small workshops
D.1	Motors (up to and including 700 W)
D.2	Contact devices
D.3	Diode, thyristor and thyratron control equipment (less than 1 000 W)
E	Gaseous discharge and other lamps
E.1	Fluorescent lamps
E.2	Neon signs
E.3	Filament lamps
F	Receiving installations
F.1	Sound broadcast receivers
F.2	Television receivers
F.3	Amplifiers and common aerial reception systems for broadcasting
F.4	Non-broadcasting receivers
G	Ignition systems of internal combustion engines
H	Identified sources other than those specified

* For convenience of analysis, the same subdivision is used for all voltage ranges. In those cases where a classification does not apply, for example, corona for low voltages, the category should remain blank

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Classification code	Description of the source
I	Other causes of complaint
I.1	Telecommunication
I.1.1	Radio communication transmitters
I.1.1.1	Fundamental radiation
I.1.1.2	Harmonic radiation
I.1.1.3	Spurious radiation
I.1.2	Telecommunication by wire
I.2	Faults of the receiving installations
I.3	Receiver characteristics
I.4	Weak or faulty signals
I.5	Atmospheric disturbances
I.6	Unidentified sources of interference
I.7	Interference not observed
J	Information technology equipment
J.1	Data processing equipment (DPE)
J.1.1	Large DPE in computer rooms
J.1.2	Smaller plugable DPE not in dedicated rooms
J.1.3	Home computers and home video games
J.2	Local area network
J.3	Commercial video games
J.4	Telephone exchanges and other digital telecommunication equipment

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Appendix II to Recommendation 2/3: Classification of sources of interference and other causes of complaint

Detailed categories

Classification code	Description of the source
A	Industrial scientific and medical RF apparatus
A.1	Industrial and scientific RF apparatus
A.1.1	Apparatus tuned to free radiation frequency
A.1.1.1	Drying non-metals
A.1.1.2	Plastic pre-heaters
A.1.1.3	Plastic seam welders
A.1.1.4	Wood glue drying
A.1.1.5	Microwave heating
A.1.1.6	Microwave cooking
A.1.1.7	Ultrasonic soldering and cleaning
A.1.1.8	Food treatment heaters (for example, fish thawing)
	...
A.1.1.20	Other
A.1.2	Not tuned to free radiation frequencies
A.1.2.1 to A.1.2.20	As for A.1.1.1 to A.1.1.20
A.2	Medical radiofrequency apparatus
A.2.1	Apparatus tuned to free radiation frequencies
A.2.1.1	Diathermy
A.2.1.2	Ultrasonic medical
A.2.1.3	Cauterization
	...
A.2.1.20	Other
A.2.2	Apparatus not tuned to free radiation frequencies
A.2.2.1 to A.2.2.20	As for A.2.1.1 to A.2.1.20
A.3	Sparking apparatus (except ignition)
A.3.1	RF excited arc welder
A.3.2	Surface erosion of plastics
A.3.3	Surface erosion of metals
A.3.4	Spectrograph
A.3.5	Spark diathermy
	...
A.3.20	Other
B	Electric power supply, distribution and traction
B.1	AC voltages exceeding 100 kV
B.1.1	Power lines overhead
B.1.1.1	Corona effect
B.1.1.2	Insulators
B.1.1.3	Presence of foreign objects on line
	...
B.1.1.20	Other

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Classification code	Description of the source
B.1.2	Generating and switching stations
B.1.2.1	Generating stations
B.1.2.2	Switching stations
B.1.2.3	Transformer stations
B.1.2.4	Saturated transformers
	...
B.1.2.20	Other
B.2	DC voltages exceeding 100 kV
B.2.1	As for B.1.1
B.2.2	Converting stations
B.3	Voltages 100 kV to 1 kV (subdivision as for B.1)*
B.4	Voltages 1 kV to 450 V (subdivision as for B.1)*
B.5	Low tension power supply and distribution (<450 V)
B.5.1	Power lines overhead
B.5.1.1	Presence of foreign objects on line
B.5.1.2	Equipment faults
	...
B.5.1.20	Other
B.5.2	Generating and switching stations
B.5.2.1 to B.5.2.20	
B.6	Electric traction
B.6.1	Railways
B.6.1.1	Overhead distribution, high voltage
B.6.1.2	Overhead distribution, medium voltage
B.6.1.3	Rail distribution
B.6.1.4	Locomotive
	...
B.6.1.20	Other
B.6.2	Tramways
B.6.3	Trolley buses
C	Electricity consumers' equipment (industrial and similar)
C.1	Generators
C.2	Motors (P > 700 W)
C.2.1	Rated power P: 700 W < P ≤ 1 000 W
C.2.1.1	Lifts
C.2.1.2	Central heating
	...
C.2.1.20	Other
C.2.2	Rated power P: 1 000 W < P ≤ 2 000 W
C.2.2.1	Lifts
C.2.2.2	Central heating
	...
C.2.2.20	Other
* Appendix A of CISPR Recommendation 22/3 gives a list of such appliances	

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Classification code	Description of the source
C.2.3	Rated power *P*: 2 000 W < *P*
C.2.3.1	Lifts
C.2.3.2	Central heating
	...
C.2.3.20	Other
C.3	Contacts
C.3.1	Lifts
C.3.2	Central heating
	...
C.3.20	Other
C.4	Ignition
C.4.1	Central heating
	...
C.4.20	Other
C.5	Rectifiers
C.6	Convertors
C.7	Diode thyristor and thyratron control equipment
C.8	Cattle fences
	...
C.20	Other installations
D	Low power appliances as normally used in households, shops, offices and small workshops
D.1	Motors (up to and including 700 W)*
D.1.1	Tools
D.1.1.1	Portable
D.1.1.2	Fixed
D.1.2	Household appliances
D.1.3	Shop and office appliances
	...
D.1.20	Other
D.2	Contact devices**
D.2.1	Thermostats
D.2.2	Other contact devices
D.3	Diode, thyristor and thyratron control equipment (less than 1 000 W)
E	Gaseous discharge and other lamps
E.1	Fluorescent lamps
E.2	Neon signs
E.3	Filament lamps
E.3.1	Vacuum
E.3.2	Gas filled
	...
E.20	Other

* Appendix A of CISPR Recommendation 22/3 gives a list of such appliances.

** See Appendix III of CISPR Recommendation 50.

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Full document details: BS CISPR 16-3:2000

Classification code	Description of the source
F	Receiving installations
F.1	Sound broadcast receivers
F.1.1	AM receiver
F.1.2	FM receiver
F.2	Television receivers
F.2.1	Local oscillator
F.2.1.1	Fundamental
F.2.1.2	Harmonic
F.2.2	Intermediate frequency radiation
F.2.3	Time base oscillator
F.2.4	Time base parasitic oscillation is, for example, Barkhausen oscillations
	...
F.2.20	Other
F.3	Amplifiers and common aerial reception systems for broadcasting
F.4	Non-broadcasting receivers
G	Ignition systems of internal combustion engines
G.1	Motor vehicles
G.2	Boats
G.3	Powered appliances (for example, lawn mowers)
	...
G.20	Other engines
H	Identified sources other than those specified
I	Other causes of complaint
I.1	Telecommunication
I.1.1	Radio communication transmitters
I.1.1.1	Fundamental radiation
I.1.1.1.1	Broadcasting stations
I.1.1.1.2	Amateur stations
I.1.1.1.3	Land mobile stations
	...
I.1.1.1.20	Other
I.1.1.2	Harmonic radiation
I.1.1.2.1	Broadcasting stations
I.1.1.2.2	Amateur stations
I.1.1.2.3	Land mobile stations
I.1.1.3	Spurious radiation
I.1.1.3.1 to I.1.1.3.20	As for I.1.1.1
I.1.2	Telecommunication by wire
I.2	Faults of the receiving installation
I.2.1	Inefficient aerial installation
I.2.2	Faulty receivers
I.2.3	Maladjustment of receiver
I.2.4	Low mains voltage

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Classification code	Description of the source
I.3	Receiver characteristics
I.3.1	Second (image) channel response
I.3.2	Other spurious responses
I.3.3	Intermodulation
I.3.4	Inadequate receiver immunity
I.4	Weak or faulty signals
I.4.1	Outside service area
I.4.2	Shadow area
I.4.3	Multipath reception
I.4.3.1	Power lines
I.4.3.2	Other
I.5	Atmospheric disturbances
I.6	Unidentified sources of interference
I.7	Interference not observed
J	Information technology equipment
J.1	Data processing equipment
J.1.1	Large DPE in computer rooms
J.1.2	Smaller plugable DPE not in dedicated rooms
J.1.3	Home computers and home video games
J.2	Local area network
J.3	Commercial video games
J.4	Telephone exchanges and other digital telecommunication equipment

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

(identical with the text taken from CISPR 8B)

2.2.1 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.

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

The following condition must be fulfilled:

$$\overline{X} + \mathrm{k}\ S_{\mathrm{n}} \leq L$$

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:

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

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

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.

2.2.2.1 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.

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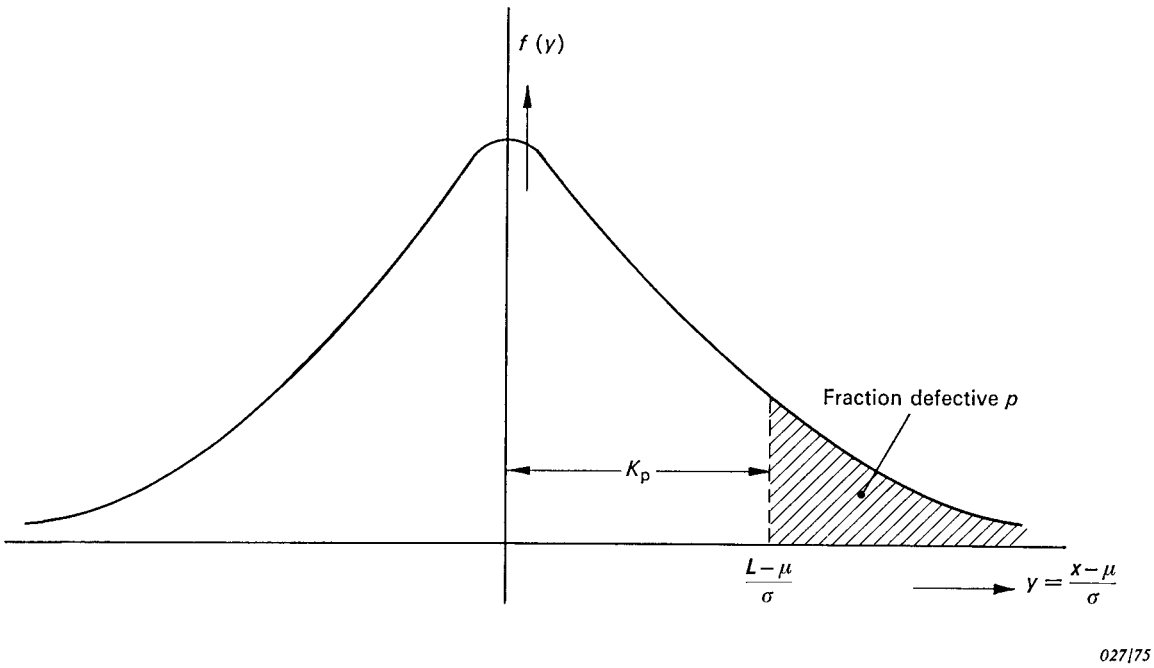
Assume: p fraction that is above the limit L (fraction defective) and $(1 - p)$ fraction of the lot below the specified limit L.

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, $\alpha = 0{,}2$ $(1 - \alpha = 0{,}8 \rightarrow 80\ \%)$ and $K_p = 0{,}84$.

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

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

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

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

By definition:

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

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

$$(L - \mu)/\sigma/\sqrt{n} = K_{\mathrm{p}}\sqrt{n}$$

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

2.2.2.2 Determination of the sample size *n*

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

$$p\left(\overline{X} + \mathrm{k}S_{\mathrm{n}} \leq L \,/\, L = \mu + K_{\mathrm{p}}\sigma\right)$$

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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:

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

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:

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

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.

2.2.2.3 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 $\mu + 2{,}4\,\sigma \leq L$.

2.2.3 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.

2.2.3.1 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.

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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:

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

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

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

$p\ (x \le c)$ 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: $\alpha = 0{,}2$ 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 $\alpha = 0{,}05$ 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.

2.2.3.2 Determination of sample size *n*

Analogue to 2.2, the acceptance probability follows from:

$$p(x \le c / p) = \beta(p)$$

If $p = 0{,}2$ then $\beta(0{,}2) = \alpha = 0{,}2$. The probability $1 - \beta(0{,}2)$ of the batch of appliances being rejected is 0,8.

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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.

2.2.3.3 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.

2.2.4 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.

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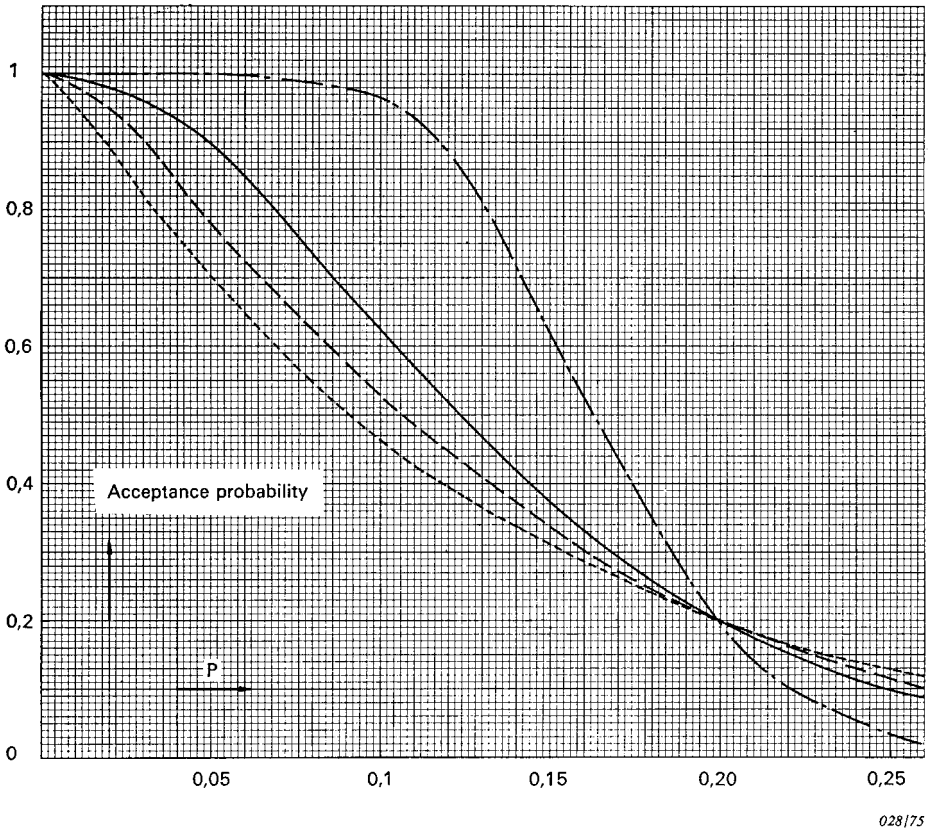
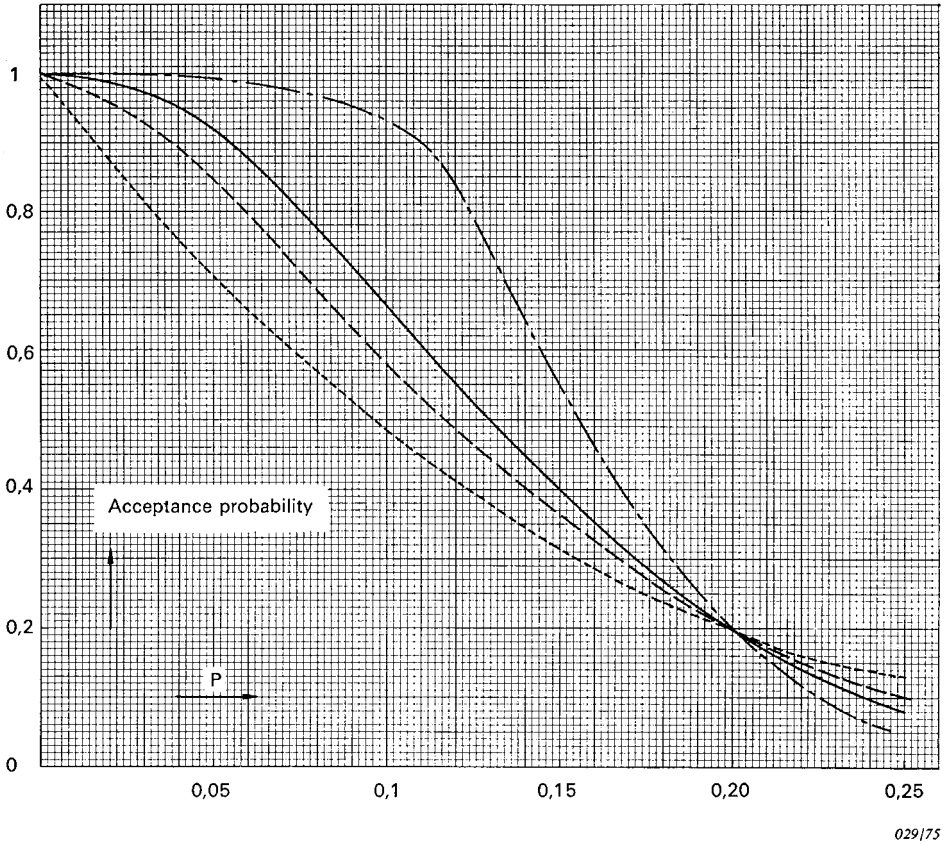


Graph 1

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

- - - - - - - - - - - - - - $n = 7$; $k = 0$
— — — — — — — $n = 14$; $k = 1$
———————— $n = 20$; $k = 2$
—·—·—·— $n = 49$; $k = 7$

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2.3 Recommendation 46/2: Significance of a CISPR limit (this recommendation replaces Recommendation 46/1, contained in CISPR 7B)

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:

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

where

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

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

x = level of individual item;

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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.

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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.

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2.4 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:

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

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

where

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

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

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

$\varphi(\gamma_0)$ 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:

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

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

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 $\Phi(\gamma_0) = \frac{n_0}{n}$ 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.

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Full document details: BS CISPR 16-3:2000

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						

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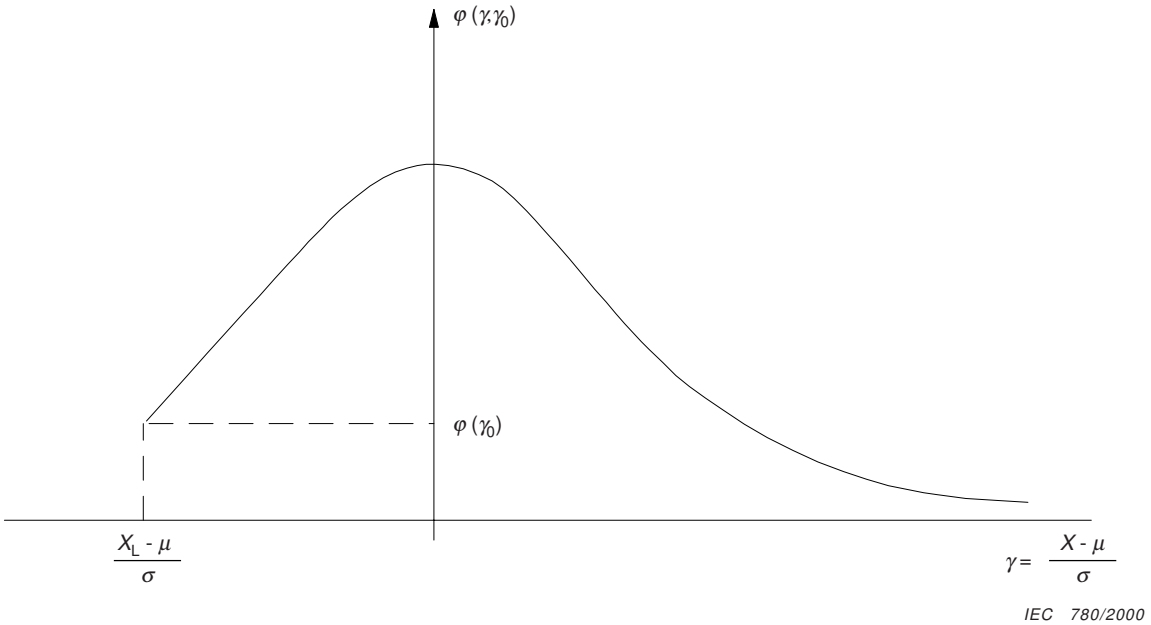

Figure 1 – The probability density function $\varphi(\gamma;\gamma_0)$

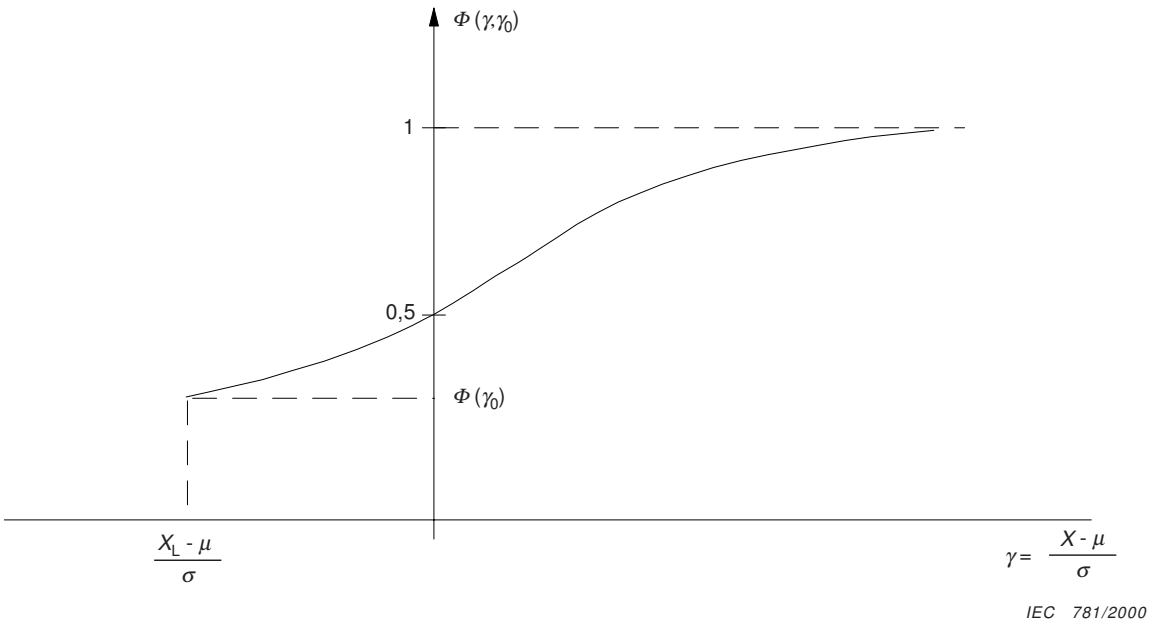

Figure 2 – The truncated distribution function $\Phi(\gamma;\gamma_0)$

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Full document details: BS CISPR 16-3:2000

Appendix to Report 59

A numerical example is given of the calculation of the average value $\overline{X}$ and the standard deviation S of the radio *disturbance* values in the case of an incompletely determined sample. In this example calculation, the sample size is six *units of equipment* (n = 6) The value of radio *disturbance* from two units (n_0 = 2) is below the limit of sensitivity of the measuring apparatus ($X < X_L$).

As outlined in the main text the calculation is performed as follows:

a) the radio *disturbance* values produced by the six units of equipment of the sample are measured. These are presented in the table below.

Unit of equipment number	1	2	3	4	5	6
The value of radio disturbance dB	19	23	20	21	$X < X_L$	$X < X_L$

b) The degree of truncation is:

$$\Phi(\gamma_0) = \frac{n_0}{n} = \frac{2}{6} = 0{,}333$$

c) Using the known value of $\Phi(\gamma_0) = 0{,}333$, the value of the normalized point of truncation is determined from the tables of the normal-distribution functions The value is: $\gamma_0 = -0{,}43$

d) From the tables of the probability density function of a normal distribution

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

$\varphi(\gamma_0) = 0{,}364$ is found.

e) From the formulae (3) and (4) assessments of the values of the statistical parameters of the truncated distribution of *disturbance* are made

$$\overline{X}_y = \frac{1}{n - n_0} \sum_{i=1}^{n-n_0} X_i = 20{,}8 \text{ dB}$$

$$S_y = \left(\frac{1}{n - n_0 - 1} \sum_{i=1}^{n-n_0} \left(X_i - \overline{X}_y\right)^2 \right)^{1/2} = 1{,}7 \text{ dB}$$

f) From the formulae (1) and (2) assessments of the values of the statistical parameters of the complete distribution of the interference values are made.

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

$$\overline{X} = 20{,}8 - \frac{1{,}7}{\left(\frac{1 - 0{,}333}{0{,}364} \left(\frac{1 - 0{,}333}{0{,}364} - 0{,}43 \right) - 1 \right)^{1/2}}$$

$$\overline{X} = 19{,}4 \text{ dB}$$

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Full document details: BS CISPR 16-3:2000

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

$$S = \frac{1{,}7}{\left(1 + \frac{0{,}364}{1 - 0{,}333}\left(-0{,}43 - \frac{0{,}364}{1 - 0{,}333}\right) + 1\right)^{1/2}}$$

S = 2,5 dB

The sample of equipment is then assessed for compliance with the limits as required in the application of non-central *t*-distribution using the formula

$$\overline{X} + kS < L$$

In this particular example, the requirement is 19,4 + 1,42 · 2,5 < *L*.

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3 A model for the calculation of limits

3.1 Introduction

A harmonized method of calculation is an important pre-condition for the efficient discussion of CISPR limits by National Committees and the adoption of CISPR Recommendations.

3.1.1 Generation of EM disturbances

CISPR Recommendations are developed for protection of radio communications and often several types of radio networks are to be protected by a single emission limit.

Most electrotechnical equipment have the potential to interfere with radio communications. Coupling from the source of electromagnetic disturbance to the radio communications installation may be by radiation, induction, conduction, or a combination of these mechanisms. Control of the pollution of the radio spectrum is accomplished by limiting at the source the levels of appropriate components of the electromagnetic disturbances (voltage, current, field strength, etc.). The choice of the appropriate component is determined by the mechanism of coupling, the effect of the disturbance on radio communications installations and the means of measurement available.

3.1.2 Immunity from EM disturbances

Most electronic equipment has the potential to malfunction as the result of being subjected to EM disturbances.

Protection of equipment is accomplished by hardening the appropriate disturbance entry route. The choice is determined by the mechanism of coupling, the effect of the disturbance on the electronic equipment and the means of measurement available.

3.1.3 Planning a radio service

Before planning radio communication service, it is necessary to decide upon the reliability of obtaining a predetermined quality of reception. This condition can be expressed in terms of the probability of the actual signal-to-interference ratio at the input of a receiver being greater than the minimum permissible signal-to-interference ratio. That is:

$$P\left[R(\mu_R;\sigma_R) \geq R_P\right] = a$$

where

$P[\ \ ]$	is the probability function;
$R(\mu_R;\sigma_R)$	is the actual signal-to-interference ratio as a function of its mean value (μ_R) and standard deviation (σ_R);
R_p	is the minimum permissible signal-to-interference ratio;
a	is a specified value representing the reliability of communications.

This probability condition is the basis for the method of determining limits.

3.2 Probability of interference

In order to make recommendations to protect adequately the radio communications systems of interest to the ITU considerable attention is paid within CISPR to the probability of interference occurring. The following is an extract from ITU-R Report 829.

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3.2.1 Derivation of probability of interference

The Radio Regulations, No. 160, defines interference as "the effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radio communication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy".

3.2.1.1 Probability of instantaneous interference

Let

A denote "The desired transmitter is transmitting";

B denote "The wanted signal is satisfactorily received in the absence of unwanted energy";

C denote "Another equipment is producing unwanted energy";

D denote "The wanted signal is satisfactorily received in the presence of the unwanted energy".

All of these statements refer to the same small-time period. Then, according to the definitions, interference means "A and B and C and D*", where D* is the negation or opposite of D: Let $P(x)$ denote the "probability of X" and $P(x|y)$ denote the "probability of x, given y". Then, the probability of interference during the small-time period is

$$P(\mathrm{I}) = P(\mathrm{A\ and\ B\ and\ C\ and\ D^*}) \tag{3.1}$$

It can be shown that this can be expressed in terms of known or computable quantities:

$$P(\mathrm{I}) = [P(\mathrm{B}|\mathrm{A}) - P(\mathrm{D}|\mathrm{A\ and\ C})]\ P(\mathrm{A\ and\ C}) \tag{3.2}$$

It may be preferable to consider the probability of interference only during the time that the wanted transmitter is transmitting. This probability is:

$$P'(\mathrm{I}) = P(\mathrm{B\ and\ C\ and\ D^*}|\mathrm{A}) \tag{3.3}$$

which can be reduced to:

$$P'(\mathrm{I}) = [P(\mathrm{B}|\mathrm{A}) - P(\mathrm{D}|\mathrm{A\ and\ C})]\ P(\mathrm{C}|\mathrm{A}) \tag{3.4}$$

3.2.1.2 Discussion of equations (3.2) and (3.4)

First, consider the difference between equation (3.2) and (3.4). The probability of interference can be interpreted as the fraction of time that interference exists. In equation (3.2), this fraction is the number of seconds of interference during a time period divided by the number of seconds of interference divided by the number of seconds the wanted transmitter is transmitting during the time period. This second fraction is larger than the first unless the wanted transmitter is on all the time. $P(\mathrm{B}|\mathrm{A})$ is just the probability that a wanted signal will be correctly received when there is no interference, often expressed as the probability that $S/N \geq R$ where S is the signal power, N is the noise power, and R is the signal-to-noise ratio required for satisfactory service. In some services, this probability is called the reliability, and is often computer when the system is designed. It can be computed if system parameters (for example, transmitter and receiver location, power, required S/N) are known using statistical data on transmission loss (for example, Recommendation 370) and statistical data on radio noise (for example, Reports 322 and 670).

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Many systems, such as satellite or microwave relay point-to-point systems, are designed so that $P(B|A) \approx 1$. In other services, such as long-distance ionospheric point-to-point services, or mobile services near the edge of the coverage area, $P(B|A)$ may be quite small. In this latter case, the probability of interference will not be small regardless of the other probabilities.

$P(D|A \text{ and } C)$ is the probability that the wanted signal will be correctly received even when the unwanted energy is present. It can be computed if there is sufficient information about the location, frequency, power, etc. of the source of unwanted energy. For examples, see the references in Report 656.

Notice that it has been assumed that $P(D|A \text{ and } C) \leq P(B|A)$; that is, if the signal can be received satisfactorily in the presence of unwanted energy, then it can surely be received satisfactorily in the absence of the unwanted energy. Thus $P(I)$ cannot be negative.

$P(A \text{ and } C)$ is the probability that the wanted transmitter and the source of unwanted energy are on simultaneously. In some situations, the wanted transmitter and source of unwanted energy may be operated independently. For example, they may be on adjacent channels, or beyond a coordination distance. In this case, $P(A \text{ and } C) = P(A)P(C)$, where $P(A)$ is the fraction of time that the wanted transmitter is emitting, and $P(C)$ is the fraction of time that the unwanted source is on.

In other situations, the operation may be highly dependent. For example, the transmitters may be co-channel stations in a disciplined mobile service. In this case $P(A \text{ and } C)$ is very small, but perhaps not zero, because a station can be located so that it causes interference even when it cannot hear the other transmitter.

The two transmitters might both operate continuously. For example, one might be part of a microwave point-to-point service, and the other a satellite sharing the same frequency band. In this case, $P(A \text{ and } C) = 1$, and the probability of interference depends entirely on the factor in square brackets in equation (3.2).

Similarly, $P(C|A) = P(C)$ if the transmitters operate independently. $P(C|A)$ is very small if the two transmitters are co-channel stations in a disciplined land mobile service; and $P(C|A) = 1$ if the unwanted transmitter is on all the time.

In general, all the terms in equations (3.2) and (3.4) affect the probability of interference, although their relative importance is different in different services.

3.3 Circumstances of interferences

In this part, general criteria are laid down for establishing RFI limits. In this case, a distinction is made for areas where close coupling exists between noise sources and victim equipment and for areas with remote coupling.

3.3.1 Close coupling and remote coupling

Although an ill-defined borderline exists between areas of close and remote coupling these concepts are generally used in the following terms.

Close coupling refers to a short distance between noise source and receiving antenna (for example, 3-30 m) which is the case for residential sources interfering with broadcasting and land mobile receivers in residential areas. In general, frequencies up to 300 MHz are considered.

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Remote coupling refers to longer distances, usually 30-300 m, which are normal between professional or semi-professional sources and receivers as in the case of individual areas. The relevant frequency spectrum is much broader: 10 kHz to 18 GHz.

For the statements given above, it follows that some similarity exists between closed coupling and near-field radiation conditions on the one hand and between remote coupling and far-field radiating conditions on the other hand. However, these concepts do not fully correspond since at frequencies below 1 MHz remote coupling may occur under near-field conditions whereas for frequencies above about 30 MHz close coupling may occur under far-field conditions. In the majority of the practical situations, however, the good correspondence between close/remote coupling and near/far-field conditions is useful in the evaluation of coupling aspects.

It should be noted that field strength measurements, which are normally used for evaluating remote coupling characteristics, are actually carried out under near-field conditions in the lower end of the frequency range.

Whereas close and remote coupling are generally used to describe a direct coupling path between noise source and receiving antenna by means of electric, magnetic or radiation fields, an additional coupling mode is conduction coupling. In this case, the noise signal is conducted by the mains network from the mains output of the source to the mains input of the receiver. Inside the receiver the noise signal is coupled from the mains terminals to sensitive circuits of the receiver.

Some well-known differences exist between near-field and far-field radiation characteristics, and therefore also for most close and remote coupling cases.

– Under far-field conditions with free-space propagation the relation between electric and magnetic components of the field is fixed and well defined, the relation under near-field conditions is completely undefined.
– Under far-field conditions the attenuation formula is

$$y = kd^x \tag{3.5}$$

where

y = attenuation factor;

d = distance;

x = propagation coefficient, which is 1 in free-space propagation and somewhat higher (1 to 1,5) for non-free-space propagation.

Under near-field conditions the propagation coefficient x is more complex and dependent on the magnetic or electric component with values between 2 and 3.

For this reason, it is much easier to develop a model for remote coupling conditions than for close coupling situations and for conduction coupling paths. Such a model is necessary to derive emission limits for a general interference environment.

3.3.2 Measuring methods

The measuring method is of major importance for the specification of an RFI limit. Several measuring methods are applied and a short survey is given in the following paragraphs. In all measurements, the measuring instrument is a selective RFI meter (CISPR receiver) as specified for the relevant frequency range.

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3.3.2.1 Interference voltage at the mains terminals

In the lower frequency range up to about 30 MHz, the mains network may conduct any injected RF energy to nearby users connected to the mains and/or couple part of the RF energy to nearby antennas in the electric, magnetic or radiation mode. Electric or magnetic field coupling to nearby antennas in this frequency range, however, is in most cases of minor importance compared with conduction coupling through the mains network. Because of the RF output voltage conduction mainly coupling through the mains network, the RF output voltage at the mains terminals is used as a measure for the interfering potential of a source in this frequency range.

This RFI voltage at the mains terminals is measured by means of an artificial mains network which isolates the source from the mains at RF frequency and which furnishes a standardized RF load to the source. The artificial mains network generally recommended by CISPR is a 50 Ω/50 μHV-network which introduces a parallel impedance of 50 Ω/50 μH V-network between each mains terminal and reference ground.

Although not recommended by CISPR yet, the asymmetric current in the mains lead, measured by means of a current probe, might be used as a measure for the radiation capability of the source.

3.3.2.2 Interference voltage at the signal terminals

Imperfections of the symmetry in circuits carrying wanted symmetrical signals will produce unwanted asymmetric signals at the terminals. In asymmetric (coaxial) terminals unwanted external currents can be conducted in the screen because of imperfect screening. These asymmetric signals and external screen currents may couple energy by inductive or radiation fields to nearby or remote antennas.

The asymmetric voltages can be measured by means of an artificial loading network. In this case the use of a delta network instead of a V-network is preferred.

3.3.2.3 RFI power measurements with the absorbing clamp

The asymmetric RF current in a lead or on the outer surface of the screen of a screened cable will radiate energy to nearby or remote antennas depending on frequency, length and configuration of the connected cable. This is particularly important at VHF and UHF in which frequency ranges the external lead of the appliance has a length which is in the order of a half wavelength or longer.

The absorbing clamp is a device which gives measuring results in a good correspondence with the interference power that can be radiated from the external lead of the appliance.

The main part of an absorbing clamp is a ferrite cylinder clamped around the disturbance carrying lead which attenuates conducted asymmetric currents by absorption. At the input end of the cylinder a current probe is fixed.

The ferrite cylinder operates as an isolator for RFI signals between mains and noise source and offers a specified, resistive impedance to the lead at the position of the current probe. So the output voltage of the current probe is a measure for the RFI power entering the absorbing clamp.

The device is clamped around the lead under test and moved along the lead to a position of maximum output reading. This operation actually adjusts the determination between source impedance and clamp input impedance (maximizing the RFI output power) through the variable lead section between source and clamp.

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Under this condition the RFI power conducted through the mains lead and measured by the absorbing clamp is a good measure for the disturbance potential. If the dimensions of the source are not small compared with wavelength, a larger part of the RFI energy will be radiated directly and the absorbing clamp measurement is less reliable.

Because broadband disturbance is, in general, of less importance at frequencies above 300 MHz the absorbing clamp was originally recommended for the measurement of small appliances in the frequency range 30 MHz to 300 MHz. There is, however, a tendency to use the absorbing clamp in the frequency range up to 1 000 MHz.

The use of the clamp is restricted at the lower part of the frequency region because of the poor absorbing characteristics of the ferrite material. It is therefore recommended for frequencies above 30 MHz.

3.3.2.4 Field-strength measurement

The unwanted field strength produced by RFI signals is likely to be the most straightforward criterion for the interference potential of an RFI source, because it is more directly comparable with the wanted field strength at the antenna of a radio receiver particularly for remote coupling analysis.

A source radiates RFI energy from its case or cabinet if a coupling path exists between internal noise source and external case or cabinet and if the dimensions of the case or cabinet are of the order of one wavelength. For practical reasons the electric component of the field is measured in the frequency range above 30 MHz (by means of dipole antennas) and the magnetic component of the field below 30 MHz (loop antennas).

Field-strength measurements have a number of practical drawbacks. The influence of surrounding reflections should be eliminated which is usually met by using an open test site. Such a test site introduces inaccuracies by the variable reflections from the operator and from the ground (influence of moisture and season) and by the interference of ambient transmitter fields. It also reduces the work time due to poor weather and other climatic conditions. These drawbacks can be partly eliminated by the use of anechoic rooms in the frequency range above 30 MHz.

Another drawback of field-strength measurements is the complex radiation diagram and its dependence on the test set-up which requires measurements in various directions and an accurately specified test set-up.

3.3.2.5 Radiation substitution measurements

In order to reduce the effect of surrounding reflections in field-strength measurements, the source under test is replaced by a radiator of specified characteristics and an adjustable output level (usually a dipole connected to a calibrated RF generator) to produce the same field strength under equal environmental conditions. The RFI of the appliance is expressed as the equivalent power radiated from the substitution radiator. This method is often used at frequencies above 1 GHz.

3.3.2.6 RFI power measurements with a reverberating chamber

The reverberating chamber method is essentially a radiation substitution method inside a screened cage and is used in the microwave frequency range. By using rotating reflection plates, the standing wave patterns inside the cage are continuously varied in such a way that the time averaged field strength is nearly independent of the position inside the cage. Therefore, the source under test and the substitution source need not be at exactly the same position and the calibration procedure for the radiated power is much simpler than in the normal substitution method.

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3.3.2.7 Frequency considerations with respect to measuring methods

As indicated earlier, the radiation of a device and the conduction and radiation of connected cables, particularly the main cables, depend on the size of the device and of the cables compared with wavelength (frequency). The following table gives a general survey of the usefulness of various measuring methods with respect to the frequency bands (subdivided according to CISPR Recommendations). It should be noted that the frequency ranges are only for indication and the quoted valuation given for guidance.

Table 1 – Guidance survey of RFI measuring methods

Frequency MHz	Terminal voltage	Asymm. current	Absorbing clamp	Field strength	Subst. radiation	Reverb. chamber
0,01 – 0,15	+	+	–	0	–	–
0,15 – 30	+	+	–	0	–	–
30 – 300	–	0	+	+	0	–
300 – 1 000	–	0	0	+	+	–
Above 1 000	–	–	–	+	+	+

where

+ = to be recommended;

0 = usable;

– = not normally usable.

3.3.3 RFI signal waveforms and associated spectra

An important aspect is the RFI spectrum which is associated with the signal waveform. As most radio services use relatively narrow frequency channels the spectrum (frequency domain) is considered of major importance compared with the waveform (time domain). Therefore the following distinction is made.

Narrowband RFI effects occur when the disturbance signal occupies a bandwidth smaller than the radio channel of interest or the measuring receiver. The disturbance spectrum may consist of a single frequency produced by a sinewave oscillator of medium or high RF power (ISM equipment) or of low power (electronic circuits, receiver oscillators). The oscillator could be modulated by the mains frequency. Oscillator frequencies can be generated over the entire usable frequency spectrum. The effect of narrowband disturbance is considered by CISPR over the frequency range 10 kHz to 18 GHz.

– Narrowband RFI from a broadband spectrum – Pulse waveforms derived from a digital clock oscillator contain discrete harmonic frequencies in a wide frequency range (broadband spectrum) For fundamental (clock) frequencies appreciably higher than the bandwidth of the radio channel, not more than one separate spectral line can coincide with the radio channel and such a spectral line is considered as narrowband RFI.

– Continuous broadband RFI – Gaussian noise generated by gas discharge devices (lighting) produces continuously a flat spectrum during the operation of the device. Repetitive pulses produce a wide spectrum containing various discrete spectral lines. At repetition rates much lower than the radio channel bandwidth many spectral lines occur within the channel (broadband RFI), for example, pulse derived from the mains frequency (commutator motors, thyristor voltage regulators).

  The frequency curve of repetitive pulses decreases above the transition frequency (the reciprocal of the pulse width) at 20 dB or 40 dB per decade, dependent on the pulse shape. Continuous broadband interference is considered by CISPR over the frequency range 150 kHz to 300 MHz.

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– Discontinuous broadband RFI – Switching operations by means of a hard contact (spark) generates short bursts of noise. Short-duration bursts of RFI cause less severe interference effects than long-duration bursts depending, however, on the average repetition rate of the bursts.

  For this reason CISPR allows a relaxation with respect to the limit of continuous interference for short bursts with a duration of less than 200 ms and with a repetition rate N of less than 30 clicks per minute. This relaxation factor equals 20 log 30/N. The frequency spectrum of such clicks is not essentially different from that of continuous broadband interference.

3.3.4 Characteristics of interfered radio services

The characteristics of the interfered radio services with respect to RFI are very important as well. The main radio services in residential areas which suffer from RFI are broadcasting and (land) mobile communication. AM sound broadcasting operates at frequencies below 30 MHz and FM (stereo) sound broadcasting between 64 MHz and 108 MHz. TV broadcasting uses various channels in the range between 50 MHz and 900 MHz, the picture signal being modulated in AM-VSB and the sound signal in either AM or FM depending on the TV standard in use. Broadcasting also takes place in the bands between 11 GHz and 13 GHz.

In residential areas with private receiving antennas the RFI radiation from noise sources and from mains cables is of major importance. Broadcast signals distributed through a cable system are less vulnerable because of the more suitable location which can be selected for the common receiving antenna, but if RFI is coupled to such an antenna the interference is distributed to all subscribers.

Satellite broadcast signals in the 12 GHz range are generally not disturbed by broadband sources because of the limited frequency spectrum of broadband sources. The risk mainly depends upon the frequencies chosen for the first intermediate frequency band at the receiver.

The annoyance to the broadcast signal depends on the RFI waveform. Narrowband and broadband sources produce different types of annoyance. Subjective tests have shown that for equivalent subjective assessment, narrowband RFI should be of significantly lower amplitude than broadband RFI (quasi-peak measured) in the 0,15 MHz to 30 MHz range.

The influence of the repetition rate of rapid pulses in a broadcast channel is accounted for in the quasi-peak detector characteristic, the effect of low rate pulses (clicks) by the 20 log 30/N relaxation to the limit. In mobile communication (mainly narrowband FM), traffic noise sources (ignition interference) are the major source of RFI. In this respect the base station antenna is in a more favourable position with respect to RFI signals than the mobile antenna because of its higher location. Mobile antennas on the other hand change their position continuously and are therefore less vulnerable to stationary noise sources.

Broadcasting and mobile services may be interfered by narrowband sources as well (ISM equipment, data processing equipment, receiver oscillators, etc.). The radiated RF power from ISM equipment may be several orders higher than the level from broadband sources although the distances between those sources (industrial areas) and the victim receivers are normally longer. The disturbing energy, however, is mainly concentrated in a very narrow frequency band. For this reason a number of frequency bands is reserved for typical ISM applications.

Other professional radio services (navigation, fixed services, satellite and microwave communication) are, in general, less vulnerable to radio interference because of the use of higher frequencies (greater than 1 000 MHz in which broadband interference is negligible) more favourable antenna locations, sophisticated systems (modulation, coding, antenna directivity) and technology (screening, filtering).

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3.3.5 Operational aspects

Noise sources in residential areas mainly consist of mass-produced devices for domestic and sometimes for professional use. Such appliances are tested according to statistical procedures which implies that a restricted percentage of *p* per cent fulfils the limit with a limited confidence *q* per cent. Small batches reduce the figures *p* and *q* and CISPR recommends a value for both *p* and *q* of 80 per cent (80 %-80 % rule). The rule is in general adequate to protect non-vital radio services like broadcast and most land mobile communication.

For critical or safety services, however, a much higher degree of confidence is necessary. The actual annoyance in an interfered radio service not only depends on the RFI field strength, but on the wanted signal level as well. The radio of wanted-to-unwanted input level which procures a specified quality of performance is called RF protection ratio. The wanted signal level depends on the natural noise level which may be much higher than the receiver noise level, particularly in the lower part of the frequency range.

In establishing limits for various types of noise sources it is important to strive for limits which have an equal effect on the radio services to be protected. The users of such a service are not interested in the type of source which causes RFI. Therefore all types of sources should be suppressed as much as possible to an equal level of noise output.

In some cases, however, this may be in contradiction with other requirements for suppression measures such as feasibility from physical conditions or from electric safety reasons and not in the least from an economic point of view.

3.3.6 Criteria for the determination of limits

3.3.6.1 Remote coupling

For remote coupling situations the field strength at a specified distance from the noise source is used as a characteristic for the interference potential of the source. The following model (see figure 15) was developed to derive radiation limits for the case of in-band interference (in the tuned channel). For the relevant radio services in the allocated frequency bands the protection ratio is determined. This protection ratio in ITU documents is given for disturbing radio service with the same modulation. The protection ratio for any disturbance radiation may be different.

From this protection ratio and from the minimum or nominal wanted field strength (field strength to be protected), the acceptable disturbance field strength at the receiving antenna input is calculated; that means that different types of modulation of the disturbance field strength has to consider a distinct from the protection ratios given in ITU documents. A minimum operational distance between noise source and receiving antenna is specified and with the use of an estimated or empirical propagation factor, the acceptable disturbance field strength at a specified measuring distance is calculated. Next some additional factors should be introduced for the screening factor of buildings and for the probability of actual interference under operational conditions. Such a probability factor should take into account statistics of antenna directivity (in the direction of the wanted transmitter and of the interference source), distance variations, propagation variations, time coincidence, etc.

The final result of this procedure is a calculated limit which is a good basis for an operational limit guaranteeing that the requirements of the protection ratio is met on a statistical basis (*x* % of the actual cases). It should be noted that reliable statistical values for most of the parameters mentioned above are not (yet) available and that in those cases rough estimations are used.

Moreover the interfering effect of out-of-band signals is more complex because of the selectivity and non-linearity characteristics of the receiver which can differ from case to case.

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3.3.6.2 Close coupling

A simple model for close coupling situations is given in figure 16. The noise source is considered as an RF generator with an e.m.f. U_s and an internal impedance Z_s for each mains connector/earth combination (for simplicity only one mains connector is shown). The mains network is connected between the noise source and the interfered receiver. The mains network offers an RF-impedance Z_m to the source and transfers the energy from the noise source to the mains input of the receiver.

In addition, part of the conducted RF energy is propagated as a magnetic and electric field. For the close coupling situations generally, near-field conditions exist (ratio electric/magnetic component undefined).

Two coupling paths exist between noise source and receiving antenna:

a) the path of disturbance conducted along the mains network, the mains supply circuit of the receiver and the coupling between supply circuit and antenna/RF circuits inside the receiver;

b) the path of disturbance conducted along and radiated by the mains network and coupled directly to the receiving antenna outside or inside the receiver.

In the case of external antennas, the RF power coupled through the external path b exceeds the power via path appreciably. Moreover the internal coupling is determined by the mains immunity characteristics of the receiver, and it has been shown that it is not difficult to control the mains immunity factor of a receiver to an adequate level. Therefore the attention is mainly focused on path b. For internal (ferrite) antennas no clear distinction can be made between paths a and b.

The approach of the modelling starts in the same way as in the case of remote coupling. The acceptable disturbance field strength at the receiving antenna is calculated from protection ratio and field strength to be protected in the relevant frequency bands. The following step is the coupling factor measured from mains input (RF-voltage) to field strength at the antenna. It is, however, more usual to define a transfer factor as the ratio of the RF-voltage injected into the mains and the antenna output voltage (for a specified antenna). This factor is known as the mains decoupling factor. Because of the wide spread in actual situations, extensive statistical material is needed to found a basis for limits derived from mains decoupling factors.

Another statistical aspect in the calculation of limits in this concept is the variation of the RF-impedance at the mains input. Although individual decoupling factors are determined by the measured voltage, independent of the actual mains impedance, the interference limit is defined for a fixed simulated impedance (artificial mains network impedance), in order to get reproducible measuring results during tests. If a noise source is coupled to an actual mains network the load impedance of that network varies from location to location and from time to time. This aspect should be considered in deriving a limit from mains decoupling measuring data.

3.3.6.3 General

The derivation of limits from a hypothetical model requires the introduction of various experimental data in such a model. As these data, as pointed out earlier, are based on statistical measurements under different actual circumstances, the usefulness of such data for general application is often debatable.

On the other hand, the implementation of suppression measures should be considered on physical, operational, manufacturing and not in the least on economic aspects. Therefore the model should be used as a worthwhile starting point but the final limit value is often the result of an agreement between parties involved after extensive considerations and negotiations.

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3.4 Basic model

This section contains the basic mathematical model used. The start-up point is the supposition that there is an identifiable probability inequality to be satisfied, and the assumption that the parameters obey a lognormal distribution.

3.4.1 Generation of EM disturbances

From the mathematical point of view any limit must be calculated with the provision that the inequality

$$z = x/y \geq 1 \tag{3.6}$$

is satisfied with some probability α.

If in (3.6) x and y are random values with log-normal distribution X (dB) and Y (dB) and with parameters μ_x (dB), μ_y (dB), σ_x (dB) and σ_y (dB) will have a normal distribution with the parameters

$$\mu = \mu_x - \mu_y$$

$$\sigma = \left[\sigma_x^2 + \sigma_y^2\right]^{1/2}$$

In this case

$$\alpha = F(\mu/\sigma)_{z=0} \tag{3.7}$$

Solving (3.7) relative to μ_x or μ_y

$$\mu_x = \mu_y + t_\alpha \sigma \tag{3.8}$$

$$\mu_y = \mu_x - t_\alpha \sigma \tag{3.9}$$

where t_α is a quantile of normal distribution, corresponding to the probability level α.

The CISPR limit L is determined for some quantile t_β in distribution of probabilities of the value x or y for which limits are established, in such a way that the following equality is true:

$$L_x = \mu_x + t_\beta \sigma_x \tag{3.10}$$

$$L_y = \mu_y - t_\beta \sigma_y \tag{3.11}$$

where t_β is a quantile for the probability level β.

Substituting (3.8) into (3.10) and (3.9) into (3.11)

$$L_x = \mu_y + t_\alpha \sigma + t_\beta \sigma_x \tag{3.12}$$

$$L_y = \mu_x - t_\alpha \sigma + t_\beta \sigma_y \tag{3.13}$$

one is enabled by the expressions obtained for the calculation of limits for different parameters, which ascertain the radio reception quality.

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Full document details: BS CISPR 16-3:2000

3.4.2 Immunity from EM disturbances

The inequality (3.6) has the form:

$x/y \geq 1$

where

x is a parameter of receptor immunity;

y is a parameter of electromagnetic environment in respect to which the immunity limit is established.

If the values X (dB) and Y (dB) are satisfactorily approximated by normal distributions with parameters μ_x, σ_x, μ_y, σ_y then

$$\sigma = \left[\sigma_x^2 + \sigma_y^2\right]^{1/2} \tag{3.14}$$

In this case, according to (3.12), the equation for the calculation of receptor immunity limits has the following form:

$$L_x = \mu_y + t_\alpha \left[\sigma_x^2 + \sigma_y^2\right]^{1/2} - t_\beta \sigma_x \tag{3.15}$$

3.5 Application of the basic model

3.5.1 Radiation coupling

This section adapts the basic model for the case where it is wished to protect a radio service when there is radiation coupling from the source of EM disturbance to the radio antenna. The actual signal-to-interference ratio R can be expressed in terms of the wanted signal, the disturbing signal, the propagation losses and the antenna gain, as follows:

$$R = E_w\,(\mu_w{:}\sigma_w) + G_w(\mu_{Gw}{:}\sigma_{Gw}) - [E_i(\mu_i{:}\sigma_i) - G_i(\mu_{Gi}{:}\sigma_{Gi}) + L_o(\mu_{Lo}{:}\sigma_{Lo}) + L_b(\mu_{Lb}{:}\sigma_{Lb}) \quad \text{dB} \tag{3.16}$$

where

E_w is the actual value of the wanted signal as a function of its mean value (μ_w) and the standard deviation (σ_w);

E_i is the value of the disturbance signal at a preset distance on a test site as a function of its mean value (μ_i) and standard deviation (σ_i);

G_w is the actual value of the antenna gain for the wanted signal as a function of its mean value (μ_{Gw}) and standard deviation (σ_{Gw});

G_i is the actual value of the antenna gain for the disturbance signal as a function of its mean value (μ_{Gi}) and standard deviation (σ_{Gi});

L_o is the actual value of the factor which takes account of the attenuation of the disturbance field strength when it is propagated through free space without obstacles as a function of its mean value (μ_{Lo}) and standard deviation (σ_{Lo});

L_b is the actual value of the factor which takes account of the attenuation of the disturbance field strength caused by obstacles in its propagation path as a function of its mean value (μ_{Lb}) and standard deviation (σ_{Lb}).

It is assumed that all the variables on the right-hand side of equation (3.16) obey a normal distribution law, then the distribution factors are related as follows:

$$\mu_R = \mu_w + \mu_{Gw} - \mu_i - \mu_{Gi} + \mu_{Lo} + \mu_{Lb} \quad \text{dB} \tag{3.17}$$

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$$\sigma_R^2 = \sigma_w^2 + \sigma_{Gw}^2 + \sigma_i^2 + \sigma_{Gi}^2 + \sigma_{Lo}^2 + \omega_{Lb}^2 \quad (3.18)$$

With a normal distribution law the reliability of obtaining the preset quality of service can be expressed by the following function of the normal probability-distribution:

$$\Phi\,[-(R_p - \mu_R) / \sigma_R] = a \quad (3.19)$$

therefore:

$$\mu_R = R_p + t_a \sigma_R \quad (3.20)$$

where $t_a = \Phi^{-1}(a)$

By combining equations (3.17), (3.18) and (3.20) an expression is obtained for the permissible mean value of the disturbance field strength at a preset distance from the source of disturbance:

$$\mu_i = \mu_w + \mu_{Gw} - \mu_{Gi} + \mu_{Lo} + \mu_{Lb} - R_p - t_a\,[\sigma_w^2 + \sigma_{Gw}^2 + \sigma_i^2 + \sigma_{Gi}^2 + \sigma_{Lo}^2 + \omega_{Lb}^2]^{1/2} \quad (3.21)$$

The mean value of the disturbance shall be below the limit, and may be specified as follows:

$$E = \mu_i + t_n \sigma_i \quad (3.22)$$

where

E is the limit for disturbance measured on a test site at a specified distance; and

t_n is a normalized argument of the distribution function which corresponds to a probability level of compliance with the limits.

The free space attenuation factor (μ_{Lo}) can be evaluated from

$$\mu_{Lo} = 20 \log_{10} [r^x/d] \quad (3.23)$$

where

r is an average distance between the disturbance source and the receiving antenna

d is the specified test distance on the measurement site;

x is the exponent which determines the actual free space attenuation rate.

Combining equations (3.21), (3.22) and (3.23) the limit is given by:

$$E = \mu_w + \mu_{Gw} - \mu_{Gi} + 20 \log_{10} [r^x/d] + \mu_{Lb} - R_p - t_n \sigma_i$$

$$- t_a\,[\sigma_w^2 + \sigma_{Gw}^2 + \sigma_i^2 + \sigma_i^2 + \sigma_{Gi}^2 + \sigma_{Lo}^2 + \omega_{Lb}^2]^{1/2} \quad (3.24)$$

CISPR Recommendation 46/1 (see 2.2) specifies that 80 % of series-produced equipment should meet the disturbance limit, and that the testing should be such that there is 80 % confidence that this is so. For these conditions t_n = 0,84.

3.5.2 Mains coupling

The required quality of radio communications is considered to be fulfilled when the probability that the actual signal-to-disturbance level is greater than the minimum acceptable value exceeds a specified value. That is

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$$P(R > R_p) \geq \alpha \tag{3.25}$$

where

R is the signal-to-disturbance ratio;

R_p is the minimum acceptable signal-to-disturbance ratio;

α is a specified value representing the reliability of communications.

The relationship between the signal-to-disturbance ratio and generated electromagnetic disturbance is:

$$R = V_w - V_i + K \quad \text{dB} \tag{3.26}$$

where

V_w is an effective value of wanted signal at the receiver input;

V_i is a value of a specified component of the electromagnetic disturbance (i.e., of voltage, field strength, power, etc.) measured in a specified way using specified equipment (i.e. a quasi-peak detector);

K is a decoupling factor defined as a ratio of V_i to an effective value of electromagnetic disturbance signal at the receiver input.

For the situations where the disturbance is coupled predominantly by conduction (frequencies below 30 MHz):

$$K = K_m + I \quad \text{dB} \tag{3.27}$$

where

K_m is a mains decoupling factor relating V_i measured at the source (by an artificial mains network) to a value of disturbance at the mains input to the receiving installation;

I is a mains immunity factor relating a value of disturbances at the mains input to an equivalent disturbance which, if applied at the antenna input of the receiving installation, would produce the same effect.

It has been established experimentally that probability distributions of V_w (dB), V_i (dB) and K for arbitrarily selected disturbance sources, radio receiving installations and distances between them is well approximated by a normal law.

A limit for electromagnetic disturbances is established for a definite quantile $E_i(p)$ in the probability distribution of E_i. A permissible value L for $E_i(p)$ is selected in such a way that at $E_i(p) = L$ a reliability of guaranteeing a radio reception which has a quality $R \geq R_p$ would be equal to the specified value τ:

$$L_{pr}(V_i) = U_{Ew} + U_k + R_p + t_p\sigma_{Ei} - t_r\left[\sigma_{Ew}^2 + \sigma_{Ei}^2 + \sigma_k^2\right]^{1/2} \tag{3.28}$$

U, σ^2 are expectations/variances of corresponding components; $t_r = \Phi^{-1}$, $t_p = \Phi^{-1}$ are arguments of a normal distribution function which is equal to t_r and p, respectively.

For series-produced articles CISPR recommends that $p = 0{,}8$; then $t_p = 0{,}84$. A value of τ is selected between 0,8 and 0,99, depending on a type of a radio network (radio broadcasting, air navigation, *et al*). When $\tau = 0{,}95$, then $t_r = 1{,}64$.

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It has been found experimentally that σ_k is the most significant factor. A change in the value of σ_k with an equivalent change in the limit for E_i results in no variation from the specified quality and reliability of radio performance. Therefore, limits are calculated for equipment located in similar conditions relative to radio receiving installations of a given radio network. For instance, in order to protect a broadcast reception in dwelling houses, it is enough to consider two groups only:

– equipment located in dwelling houses or connected to their supply mains;

– equipment located outside dwelling houses.

The second group, on the basis of economic considerations and separation distance, is divided into the following subgroups: power lines; electric transport; motor vehicles; industrial equipment located in an assigned territory; etc.

3.6 An alternative method used for ISM equipment

3.6.1 Introduction

The purpose of this clause is to review studies made for the derivation of CISPR limits for the protection of telecommunications from interference from ISM equipment and to conclude from these a recommended method which will meet the objectives of CISPR and ITU. This clause deals only with radiation which occurs outside the bands designated by ITU for ISM use.

3.6.2 Derivation of limits

The full range of parameters to be taken into account in the derivation of limits is shown in table II together with the major services requiring protection. Appendix A provides a model for the calculation of limits.

3.6.2.1 Protection of communication services

The wanted field strength to be protected, the protection ratio required for the different types of ISM equipment, the distance from the source at which protection is necessary and the attenuation law to be used in the calculation are important. These are matters in which ITU support is essential.

3.6.2.2 Proposed model for use in calculating disturbance limits

The factors that have traditionally been included in models for predicting interference from radio-frequency sources are listed in columns 1 to 10 of table 2 by assigning appropriate values to each parameter, for example, field strength to be protection, protection ratio, etc., worst-case limits for protecting the various communication services from interference from ISM equipment may be determined. However, a model which is based on worst-case parameters is both technically and economically unrealistic since it ignores the fact that there have been very few instances of interference attributed to ISM equipment. It is therefore critical that the experience in this subject should be taken into account. Thus, the benefits of worldwide experience in this subject can be included although it is recognized that the probability can only be an estimate at present because so many complex factors are involved as shown in 3.7.2.3. Determination of numerical values of the probability for the various services is urgently required and studies are being undertaken in several countries.

3.6.2.3 Probability factors

Probability of coincidence of adverse factors:

$$P = P_1 \times P_2 \rightarrow P_{10}$$

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where

P_1 is the probability that the major lobe of the ISM radiation is in the direction of the victim receiver;

P_2 is the probability of directional receiving aerials having maximum pick-up in the direction of the disturbing source;

P_3 is the probability that the victim receiver is stationary;

P_4 is the probability of ISM equipment generating a disturbing signal on a critical frequency;

P_5 is the probability that the relevant harmonic is below the limit value;

P_6 is the probability that the type of disturbing signal being generated will produce a significant effect in the receiving system;

P_7 is the probability of coincident operation of the ISM source and the receiving system;

P_8 is the probability of the disturbing source being within the distance at which interference is likely to occur;

P_9 is the probability of coincidence of limit value of ISM radiation with edge of service area condition is for the protected service;

P_{10} is the probability that buildings provide attenuation.

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