



**Atacama
Large
Millimeter
Array**

ALMA Power Quality (Compatibility Levels) Specification


ALMA-80.05.00.00-001-C-SPE

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Change Record

Version	Date	Affected Section(s)	Change Request #	Reason/Initiation/Remarks
A	2002-06-19	All	N.A.	First Issue
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C	2003-12-15	2.1.2.2 & 3	ALMA-80.05.00.00-001-B-CRE	<p>“ALMA Environmental Site Specifications” has been renamed “ALMA Environmental Specification” in accordance with the actual name and version of the document.</p> <p>ALMA-SPE-ESO-12000-00007 ALMA System Wide Requirements - Electromagnetic Compatibility Renamed to ALMA-80.05.01.00-001-A-SPE ALMA Electromagnetic Compatibility Requirements</p> <p>Signature fields updated</p>



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1. DESCRIPTION

This document deals with the power quality (compatibility levels) of the AC power systems of the ALMA Observatory.

1.1 Purpose

In this document ‘compatibility levels¹’ are sets. The compatibility levels - by their own definition - constitute a *neutral* reference that is valid for all pieces of equipment that are connected to a power system whichever their nature and function.

Requirements originate from these compatibility levels not only for the power generation and distribution systems but also for all pieces of equipment (antennas, UPS inputs, power drives, etc.) that will be fed by these systems. The loads (equipment) have to exhibit emission limits and immunity limits that are consistent with the compatibility levels. Emission and immunity limits of the equipment are specified by the ALMA EMC Specification.

The power quality is the result not only of the *robustness* of the power generation and distribution systems but also of the *quality* of the equipment fed by these systems.

1.2 Scope


This Specification (SPE) is applicable to all the AC power systems pertaining to the Atacama Large Millimeter Array (ALMA).

It sets compatibility levels for ALMA power systems for the following low-frequency conducted disturbances:

- harmonics;
- interharmonics;
- voltage fluctuations and flicker;
- voltage unbalance;
- power frequency variation;
- mains signaling.

¹ **(Electromagnetic) compatibility level** (IEV 161-03-10)

The specified electromagnetic disturbance level used as a reference level for co-ordination in the setting of emission and immunity limits.

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Explanatory notes are provided about voltage dips and short supply interruptions, transient overvoltages and DC components.

The emission limits and immunity limits to be fulfilled by (applicable to) the equipment to be operated within the ALMA Project are set by another document, namely, the ALMA Specification 2.1.2.1 'ALMA'.

The definitions of compatibility level, emission limit and immunity limit are provided in section 2.4 'Glossary'.

The Appendix 8.1 'Application of EMC terms and definitions (informative)' explains the relations among the compatibility levels (specified by this document for ALMA power systems) and the emission limits and immunity limits (specified by the ALMA Specification 2.1.2.1 for the equipment to be operated within the ALMA Project).

The compatibility levels valid for the distribution systems fed by UPSs are those standardized by 2.1.1.6 (IEC 61000-2-4) for Class 1 electromagnetic environment.

2. REFERENCES

2.1 Applicable Documents and Drawings

The following Applicable Documents and Drawings of the exact issue shown form a part of the present document to the extent specified herein. Where no issue or date is indicated, the latest editions/revisions thereof and any amendments or supplements thereto in effect on the date of the contract documents that enforce the present specification shall be taken as valid. In the event of conflict between the Applicable Documents and Drawings referenced herein and the contents of the present document, the contents of the present document shall be considered a superseding requirement.

2.1.1 International Standards

2.1.1.1 IEC 60050-161

International Electrotechnical Vocabulary
Chapter 161: Electromagnetic compatibility

2.1.1.2 European Standard EN 50160

"Voltage characteristics of electricity supplied by public distribution systems", November 1999.



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2.1.1.3 IEC 61000

“Electromagnetic compatibility (EMC)”the entire series is applicable; in particular - but not exclusively - the following parts of IEC 61000 are relevant to the scope of this specification

2.1.1.4 IEC 61000-2-1

“Electromagnetic compatibility (EMC) - Part 2: Environment - Section 1: Description of the environment - Electromagnetic environment for low-frequency conducted disturbances and signalling in public power supply systems”

2.1.1.5 IEC 61000-2-2

“Electromagnetic compatibility (EMC) - Part 2-2: Environment - Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems”

2.1.1.6 IEC 61000-2-4

“Electromagnetic compatibility (EMC) - Part 2-4: Environment - Compatibility levels in industrial plants for low-frequency conducted disturbances

2.1.1.7 IEC 61000-2-8

“Electromagnetic compatibility (EMC) - Part 2-8: Environment - Voltage dips and short interruptions on public electric power supply systems with statistical measurement results


2.1.2 ALMA Specifications and Technical Reports

2.1.2.1 ALMA-80.05.01.00-001-A-SPE

ALMA Electromagnetic Compatibility Requirements

2.1.2.2 ALMA-80.05.02.00-001-B-SPE

ALMA Environmental Specification

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2.1.3 Related Interface Control Drawings

Not Applicable.

2.2 Reference Documents and Drawings

The following documents contain additional information relevant to the subject matter of this specification.

In the event of conflict between the documents listed hereafter and the contents of this Specification (respectively, of the documents enforced in section 2.1 ‘Applicable Documents and Drawings’), the contents of this Specification (respectively, of the documents enforced in section 2.1 ‘Applicable Documents and Drawings’) shall be considered a superseding requirement.

2.2.1.1 UNIPEDE Report 91en 50/S.1

“Voltage dips and short interruptions in medium voltage public electricity supply systems”

2.2.1.2 *FIJA REGLAMENTO DE LA LEY GENERAL DE SERVICIOS ELECTRICOS*


Santiago de Chile, 12 diciembre 1997, N° 327(downloadable under *Marco Regulatorio* at http://www.sec.cl/index_electricidad.htm)

2.2.1.3 Measurement guide for voltage characteristics - Electricity product characteristics and electromagnetic compatibility

Union of the Electricity Industry - EURELECTRIC - Brussels (Belgium)
July 1995, Ref: 23002Ren9531

2.3 Abbreviations and Acronyms

a.c.; AC	alternating current
ALMA	Atacama Large Millimeter Array
AOS	Array Operation Site
AUI	Associated Universities, Inc. (www.aui.edu)
d.c.; DC	direct current


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EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
ESO	European Southern Observatory (www.eso.org)
EURELECTRIC	Union of the Electricity Industry, Brussels, Belgium (http://public.eurelectric.org/Content/Default.asp)
HV	high voltage ($U > 1000 \text{ VAC}$ for the sake of safety; otherwise $U > 35 \text{ kV}$)
IEC	International Electrotechnical Commission (www.iec.ch)
IEV	International Electrotechnical Vocabulary (http://domino.iec.ch/iev/iev.nsf/Welcome?OpenForm)
LV	low voltage ($U \leq 1000 \text{ VAC}$)
MV	medium voltage ($1000 \text{ VAC} < U \leq 35000 \text{ VAC}$)
NA	Not Applicable
NRAO	National Radio Astronomy Observatory (www.nrao.edu)
OSF	Operations Support Facility
P	active power (units: kW, MW)
RD	Related Document
r.m.s.; RMS	root mean square
S	apparent power (units: kVA, MVA)
SPE	Specification
TBC	To Be Confirmed
TBD	To Be Defined
THD	total harmonic distortion
UPS	uninterruptible power supply

2.4 Glossary

The terms of importance in the context of this specification are defined below. For readers' convenience, many definitions are also presented as footnotes.

When a definition is identical with the one given in the International Electrotechnical Vocabulary (IEV – Applicable Document 2.1.1.1), the definition provided in this document is followed by its number as given in IEC 60050(161). Where it differs, the

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IEV number is followed by "/A", or it is indicated that the term has not been defined in IEC 60050(161).

The terms and their definitions can be divided into three groups:

- 1) **Basic terms**, for example electromagnetic compatibility, emission, immunity and level;
- 2) **Combined terms**, which combine basic terms, for example emission level, compatibility level and immunity limit.
- 3) **Interrelated terms**, which interrelate combined terms, for example emission margin and compatibility margin.

2.4.1 Basic terms

electromagnetic environment (161-01-01):

The totality of electromagnetic phenomena existing at a given location.

NOTE – In general, the electromagnetic environment is time dependent and its description may need a statistical approach.

electromagnetic disturbance (161-01-05):

Any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter.

NOTE - An electromagnetic disturbance may be an electromagnetic noise, an unwanted signal or a change in the propagation medium itself.


electromagnetic interference; EMI (abbreviation) (161-01-06):

Degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance.

NOTES

- 1 - In French, the terms "perturbation électromagnétique" and "brouillage électromagnétique" designate respectively the cause and the effect, and should be used indiscriminately.
- 2 - In English, the terms "electromagnetic disturbance" and "electromagnetic interference" designate respectively the cause and the effect, but they are often used indiscriminately..

electromagnetic compatibility; EMC (abbreviation) (161-01-07):

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The ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

(electromagnetic) emission (161-01-08):

The phenomenon by which electromagnetic energy emanates from a source.

degradation (of performance) (161-01-19):

An undesired departure in the operational performance of any device, equipment or system from its intended performance.

NOTE - The term "degradation" can apply to temporary or permanent failure.

immunity (to a disturbance) (161-01-20):

The ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

(electromagnetic) susceptibility (161-01-21):

The inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

NOTE - Susceptibility is a lack of immunity.

level (of a time varying quantity) (161-03-01):

Value of a quantity, such as a power or a field quantity, measured and/or evaluated in a specified manner during a specified time interval.

NOTE - The level of a quantity may be expressed in logarithmic units, for example decibels with respect to a reference value.

2.4.2 Combined terms

emission level (of a disturbing source) (161-03-11):

The level of a given electromagnetic disturbance emitted from a particular device, equipment or system.

emission limit (from a disturbing source) (161-03-12):

The specified maximum emission level of a source of electromagnetic disturbance.

immunity level (161-03-14):

The maximum level of a given electromagnetic disturbance incident on a particular device, equipment or system for which it remains capable of operating at a required degree of performance.



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immunity limit (161-03-15):

The specified minimum immunity level.

disturbance level (161-03-29):

The level of an electromagnetic disturbance existing at a given location, which results from all contributing disturbance sources.

(electromagnetic) compatibility level (161-03-10):

The specified electromagnetic disturbance level used as a reference level for co-ordination in the setting of emission and immunity limits.

NOTES

1. By convention, the compatibility level is chosen so that there is only a small probability that it will be exceeded by the actual disturbance level. However electromagnetic compatibility is achieved only if emission and immunity levels are controlled such that, at each location, the disturbance level resulting from the cumulative emissions is lower than the immunity level for each device, equipment and system situated at this same location.
2. The compatibility level may be phenomenon, time or location dependent.

2.4.3 Interrelated terms

emission margin (161-03-13):

The ratio of the electromagnetic compatibility level to the emission limit.

immunity margin (161-03-16):

The ratio of the immunity limit to the electromagnetic compatibility level.

(electromagnetic) compatibility margin (161-03-17/A):


The ratio of the immunity limit to the emission limit.

NOTE

The compatibility margin is the product of the emission margin and the immunity margin.


GENERAL NOTE

If the levels are expressed in dB(...), in the above margin definitions "difference" should be read instead of "ratio" and "sum" instead of "product".

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3. OPERATING ENVIRONMENT

The environmental conditions existing at sites relevant to the ALMA Project are specified by the Applicable Document 2.1.2.2 ALMA-80.05.02.00-001-B-SPE 'ALMA Environmental Specification'.

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4. TECHNICAL REQUIREMENTS

NOTE

The requirements within the present document are numbered according to the following code

EPQU-XXXXX-YY/Z(ZZ)

where

EPQU stands for ‘Engineering Specification: Power Quality (Compatibility Levels)’;

XXXXX is the consecutive number 00010, 00020, ... (the nine intermediate numbers remaining available for future revisions of this document);

YY describes the requirement revision and starts with 00;

Z(ZZ) describes the verification method(s) where T stays for test, I for inspection, R for review of design, A for analysis.

4.1 General


The present chapter sets the compatibility levels for the low-frequency conducted disturbances for the AC power distribution system of the ALMA sites. The relations among these compatibility levels and the actual disturbance levels that will be measured on the low-voltage power distribution system at the ALMA sites are explained within appendix 8.1 ‘Application of EMC terms and definitions (informative)’.

On medium voltage networks associated with downstream low voltage networks, the actual disturbance levels are generally lower than on the low voltage networks. This is especially the case for harmonics and interharmonics. This is also true for high voltage networks associated with downstream medium voltage networks. The following requirement follows from these considerations.

EPQU-00010-00/T; A

ALMA medium-voltage and high-voltage power systems shall conform to compatibility levels - especially those set by the sections 4.1.1.1, 4.1.1.2 and 4.1.1.3 hereafter - adequately lower than those specified by this document.

The relevant margins shall be those indicated in the Applicable Documents 2.1.1.2 (European Standard EN 50160) and/or 2.1.1.3 (IEC 61000).

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EPQU-00020-00/T; A

The compatibility levels valid for the distribution systems fed by UPSs are those standardized for Class 1 electromagnetic environment by 2.1.1.6 (IEC 61000-2-4).

The UPS inputs will operate in the electromagnetic environment described by the present document and, therefore, their emission and immunity levels shall conform to what specified by the ALMA EMC Specification 2.1.2.1 (ALMA).

4.1.1.1 Harmonic voltages - Compatibility levels for individual harmonic voltages

EPQU-00030-00/T; A


The compatibility levels for individual harmonic components² of the voltage in the ALMA low voltage power systems shall be those in the following table.

Odd harmonics non-multiple of 3		Odd harmonics multiple of 3		Even harmonics	
Harmonic order h	Harmonic voltage %	Harmonic order h	Harmonic voltage %	Harmonic order h	Harmonic voltage %
5	6	3	5	2	2
7	5	9	1.5	4	1
11	3.5	15	0.4	6	0.5
13	3	21	0.3	8	0.5
17	2	21 < h ≤ 45	0.2	10	0.5
17 < h ≤ 49	$2.27 \times (17/h) - 0.27$			10 < h ≤ 50	$0.25 \times (10/h) + 0.25$

Table 1 Compatibility levels for individual harmonic voltages
(RMS values as percent of the RMS value of the fundamental component)

² **Harmonic (component)** (IEV 161-02-18)

A component of order greater than one of the Fourier series of a periodic quantity.

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EPQU-00040-00/T; A

The levels given in Table 1 for odd harmonics that are multiples of 3 apply to zero-sequence harmonics.

NOTE

On a three-phase network without a neutral conductor or without load connected between line and ground, the values of the 3rd and 9th harmonics may be much lower than the compatibility levels, depending on the unbalance of the system.

EPQU-00050-00/T; A

With reference to very short-term effects, the compatibility levels for individual harmonic components of the voltage are the values given in Table 1 multiplied by a factor k , where k is calculated as follows:

$$k = 1.3 + (h - 5) \times 0.7/45$$

4.1.1.2 Harmonic voltages - Compatibility levels for total harmonic factor

EPQU-00060-00/T; A

The compatibility level for the voltage total harmonic factor³ shall be

$$\text{THD} = 8\%.$$

EPQU-00070-00/T; A

The level THD = 8% refers to continuous values. The compatibility level of the voltage total harmonic distortion corresponding to transient harmonics shall be


$$\text{THD} = 11\%.$$

NOTES

1. The total harmonic factor (THD) is evaluated considering voltage components from the 2nd to the 50th order.
2. The limitation of the total harmonic factor THD is aimed to prevent the simultaneous presence of several harmonic components with high amplitude.

³ **total harmonic factor**; total harmonic distortion (deprecated in this sense); (IEV 101-14-55)

Ratio of the root-mean-square value of the harmonic content of an alternating quantity to the root-mean-square value of the quantity.

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3. Commutation notches, in so far as they contribute to harmonic levels in the supply voltage, are covered by the compatibility levels given above in sections 4.1.1.1 and 4.1.1.2.

4.1.1.3 Harmonic voltages – Compatibility levels for inter-harmonic voltages

EPQU-00080-00/T; A

The compatibility level for each inter-harmonic⁴ voltage component shall be

0.2%


of the nominal supply voltage.

NOTES

1. This level refers to continuous values. For transient voltage inter-harmonics, values up to and including 1.5 times the permanent level are allowed during a maximum duration of 10% of any observation period of 2.5 minutes.
2. Knowledge of the electromagnetic disturbance involved in interharmonics voltages is still developing. See Annex B of Ed. 2.0, 2002-03, of 2.1.1.5 (IEC 61000-2-2).

⁴ **interharmonic component**

A component having an interharmonic frequency. Its value is normally expressed as an RMS value. For brevity, such a component may be referred to simply as an “*interharmonic*”..

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4.1.1.4 Voltage fluctuations⁵, rectangular (step) voltage change⁶ and flicker⁷

EPQU-00090-00/T; A

The compatibility levels for rectangular (step) voltage changes shall be those standardized by Figure 1 (corresponding to Figure 1 of Ed. 2.0, 2002-03, of the Applicable Document 2.1.1.5 (IEC 61000-2-2)).

The severity of flicker resulting from non-rectangular voltage fluctuations may be found either by measurement with a flickermeter or by the application of correction factors as indicated in IEC 61000-3-3.

⁵ **voltage fluctuation** (IEV 161-08-05)

A series of voltage changes or a continuous variation of the r.m.s. or peak value of the voltage.

⁶ **voltage change** (IEV 161-08-01)

A variation of the r.m.s. or peak value of a voltage between two consecutive levels sustained for definite but unspecified durations.

Note. - In the two definitions above, whether the r.m.s. or peak value is chosen depends upon the application, and which is used should be specified.

⁷ **flicker** (IEV 161-08-13)

Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time.



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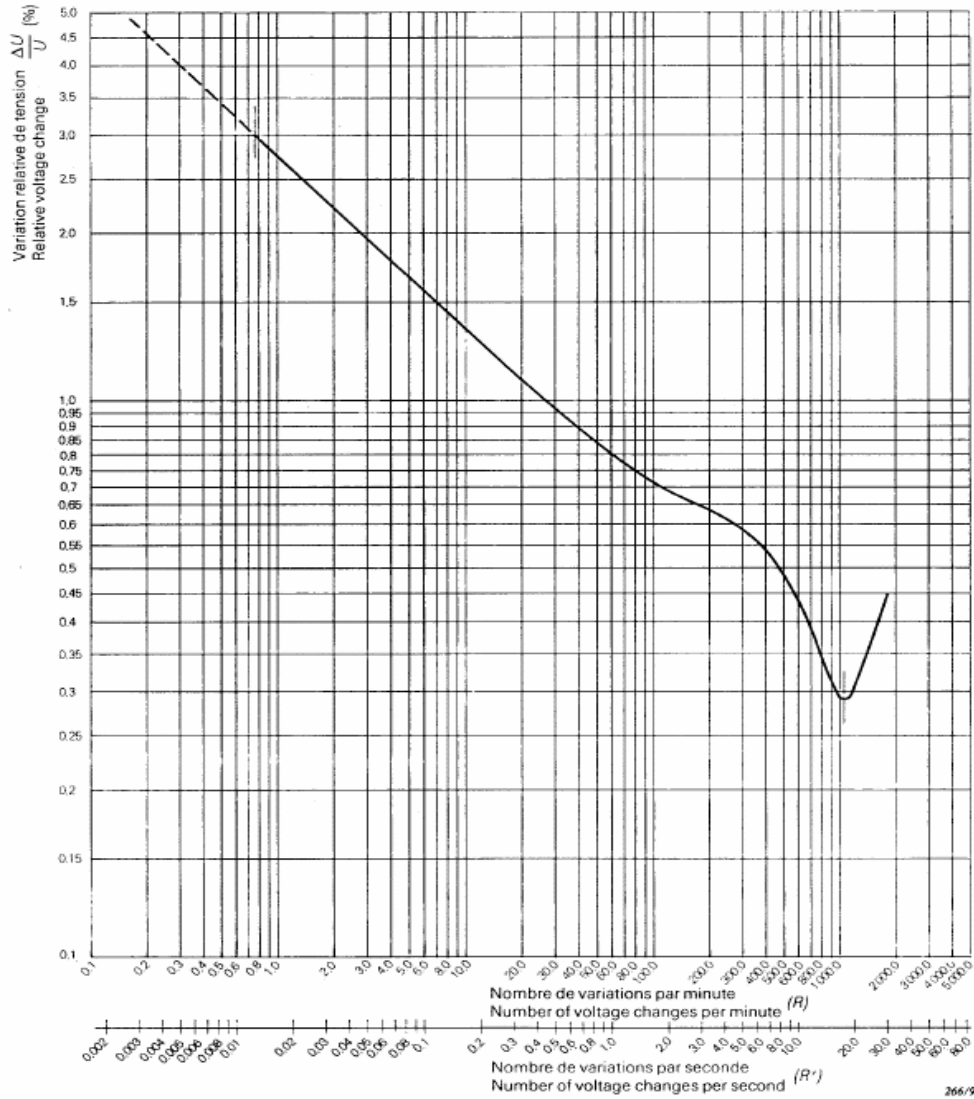



Figure 1 - Step voltage changes and light flicker: Magnitude of maximum permissible percentage voltage changes $\Delta U/U$ (%) with respect to number of voltage changes per second or minute

4.1.1.5 Flicker ⁷

EPQU-00100-00/T; A

The compatibility levels of flicker severity shall be:

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short-term $P_{st} = 1$;

long-term $P_{lt} = 0.8$.

4.1.1.6 Voltage fluctuations – infrequent step voltage changes

EPQU-00110-00/T; A

The compatibility levels for infrequent (some per day) step voltage changes will be

10%

of the nominal supply voltage.

4.1.1.7 Voltage dips and supply interruptions

NOTE.

Voltage dips⁸ and supply interruptions⁹ are unpredictable, largely random events arising mainly from electrical faults on the power supply system or large installations. They are best described in statistical terms.

A voltage dip is a two-dimensional disturbance phenomenon, since the level of the disturbance increases with both the depth ($\Delta U/U_N$) and the duration (Δt) of the dip.

Short (up to 3 minutes long) supply interruptions are frequently preceded by voltage dips.

Immunity of electrical equipment is not, in the strict sense, an appropriate concept in the case of supply interruptions or of the more severe voltage dips. That is because no electrical device can continue to operate as intended in the absence of its energy supply.

⁸ **Voltage dip** (IEV 161-08-10)

A sudden reduction of the voltage at a point in an electrical system followed by voltage recovery after a short period of time from a few cycles to a few seconds.

⁹ **Supply interruption** (from EN50160:1999, “Voltage characteristics of electricity supplied by public distribution systems”)

A condition in which the voltage at the supply terminals is lower than 1% of the declared voltage, U_c . A supply interruption can be classified as:

- **prearranged**, when consumers are informed in advance, to allow execution of scheduled works on the distribution system;
- **accidental**, caused by permanent or transient faults, mostly related to external events, equipment failures or interference. An accidental interruption is classified as:
 - **a long interruption** (longer than three minutes) caused by a permanent fault,
 - **a short interruption** (up to three minutes) caused by a transient fault.



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This is the reason for which international EMC standards do not provide compatibility levels for these disturbances but only typical ranges given for guidance purposes only.

The following average quantities may be defined:

- average values of depth, duration and yearly frequency of voltage dips;
- average frequency (rate) and average duration of supply interruptions, while distinguishing between the values valid for prearranged any for accidental interruptions.

See also the Applicable Document 2.1.1.7 (IEC 61000-2-8).

4.1.1.8 Three-phase voltage unbalance¹⁰

EPQU-00120-00/T; A

The compatibility level for negative sequence voltage unbalance will be

$$\tau = U_{\text{neg}}/U_{\text{pos}} = 2\%$$

This level applies in relation to long term effects, i.e., for durations of 10 minutes or longer.

4.1.1.9 Transient overvoltages

NOTE

Having regard to the differences, in respect of amplitudes and energy content, between transient overvoltages of different origins (mainly lightning and switching surges), compatibility levels are not specified by the IEC.

In relation to insulation co-ordination, IEC 60664-1 applies.

4.1.1.10 Power frequency variation

EPQU-00130-00/T; A

The compatibility levels for variation of the fundamental frequency ($f_N = 50$ Hz) shall be

¹⁰ **Voltage imbalance; Voltage unbalance** (IEV 161-08-09)

In a polyphase system, a condition in which the r.m.s. values of the phase voltages or the phase angles between consecutive phases are not all equal.



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- for the local generation alternatives: $\Delta f/f_N = \pm 2\%$, i.e., $\Delta f = \pm 1.0$ Hz;
- for the commercial power alternatives: $\Delta f/f_N = \pm 1\%$, i.e., $\Delta f = \pm 0.5$ Hz.

4.1.1.11 DC components in the AC power system

NOTE

A DC component at a significant level can arise when certain non-symmetrically controlled loads are connected.

In the event that a DC component is present in the supply voltage, a DC current can cause unsymmetrical magnetization in distribution transformers, leading to overheating. Moreover, in flowing through the earth, such a current leads to increased corrosion of metal fixtures underground.

The critical point is the level of the DC current. The value of the DC voltage depends not only upon the DC current but also on other factors, especially the resistance of the network at the point to be considered.

Therefore a compatibility level for the DC component of the AC voltage is not specified by the IEC.

4.1.1.12 Mains signalling¹¹

Current ESO plans are not to use and even to forbid the adoption of mains signalling voltages within the ALMA medium- and low-voltage power distribution systems.

Should the ALMA Sites be supplied electric power by a commercial utility, the following information shall be gathered from the utility.


- Whether mains signalling is/will be used in the portion of utility's power system that may supply the AOS and/or the OSF.
- If yes, whether the amplitude of the voltages injected by the utility/utilities in its/their system/s comply with the following compatibility levels.

NOTE

The frequency ranges mentioned hereafter are nominal and are a matter of common practice.

¹¹ **Mains signalling**

Use of the distribution network for the transmission of signals.

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EPQU-00140-00/T; A

Ripple control systems (110 Hz to 3000 Hz)

The amplitude of the signal U_s of ripple control systems in the range of 110 Hz to 3000 Hz shall not exceed the levels given in Table 1 of section 4.1.1.1 'Harmonic voltages - Compatibility levels for individual harmonic voltages' for odd harmonics non-multiple of 3.

Alternatively, the ripple control systems shall comply with the so-called Meister curve.

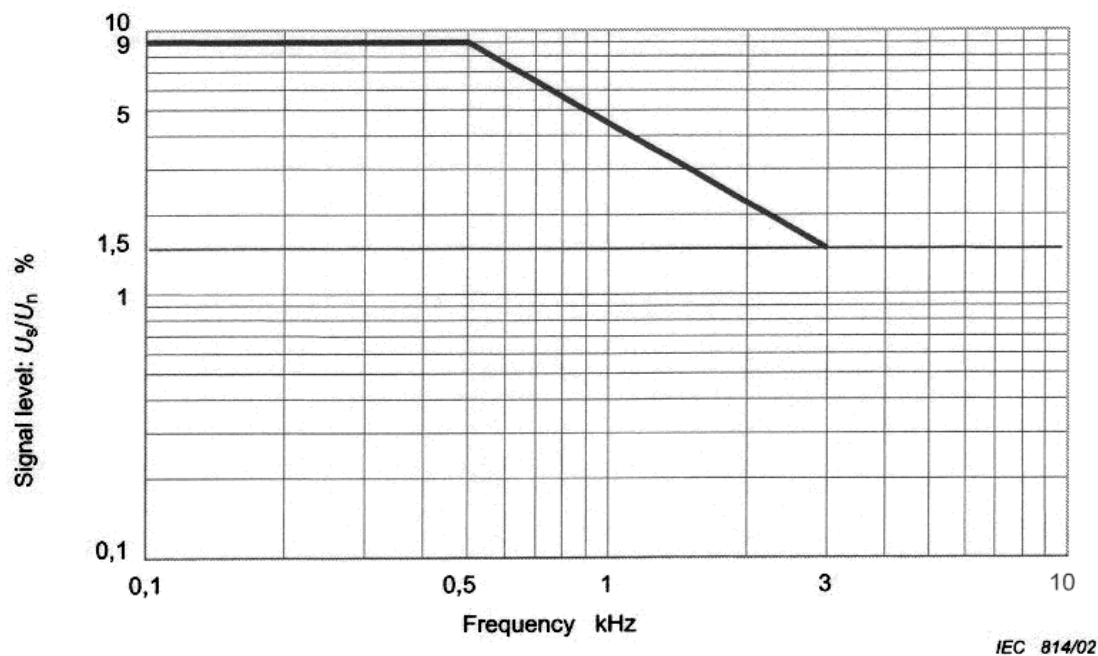



Figure 2 - Meister curve for ripple control systems in public networks (100 Hz to 3000 Hz)

EPQU-00150-00/T; A

Medium frequency power-line carrier systems (3 kHz to 20 kHz)

Signal levels U_s of medium-frequency (3 ÷ 20 kHz) power-line carrier systems shall not exceed 2% of the nominal supply voltage.

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EPQU-00160-00/T; A

Radio-frequency power-line carrier systems (20 kHz to 150 kHz)

Signal amplitudes U_s of radio-frequency (20 ÷ 150 kHz) power-line carrier systems shall not exceed 0.3% of the nominal supply voltage.

EPQU-00170-00/T; A

Spurious output frequencies shall comply with the radio interference limits.

5. INTERFACES TO OTHER SUBSYSTEMS

Not applicable


6. MAINTENANCE AND RELIABILITY

Not applicable

7. MANUFACTURE AND ASSEMBLY

Not applicable

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8. APPENDIXES

8.1 Application of EMC terms and definitions (informative)

The contents of the Appendixes 8.1 ‘Application of EMC terms and definitions (informative)’ and 8.2 ‘Compatibility level and margin (informative)’ are provided as a guidance in understanding the relations among the compatibility levels (specified by this document for ALMA power systems) and the emission limits and immunity limits specified by the ALMA EMC Specification 2.1.2.1 (ALMA) for the equipment to be operated within the ALMA Project.

In the event of conflict between the contents of these Appendixes and the rest of this Specification, the rest of this Specification shall be considered a superseding requirement.

8.1.1 General

The definitions given in section 2.4 ‘Glossary’ are basic, conceptual definitions. When they are applied to assign specific values to the levels in a particular case, several considerations should be borne in mind. A number of these are given in this section, together with examples which will elucidate them.

The basic devices of systems can be divided into two groups

- 1) *emitters*, i.e. devices, equipment or systems which emit potentially disturbing voltages, currents or fields, and
- 2) *susceptors*, i.e. devices, equipment or systems whose operation might be degraded by those emissions.


Some devices may belong simultaneously to both groups.

8.1.2 Relation between various levels

8.1.2.1 Emission and immunity level/limit

Figure 3 shows a possible combination of an emission and an immunity level and their associated limits as a function of some independent variable, for example the frequency, for a single type of emitter and a single type of susceptor.

In Figure 3 the emission level is always lower than its maximum permissible level, i.e., the emission limit, and the immunity level is always higher than its minimum required level, i.e., the immunity limit. Hence, the emitter and the susceptor comply with their

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prescribed limit. In addition the immunity limit has been chosen above the emission limit, and it has been assumed that the levels and limits are continuous functions of the independent variable. These levels and limits may also be discrete functions of some independent variable, see the example in section 8.1.2.2 ‘Compatibility level’.

The following considerations should be kept in mind.

Consideration A

By drawing the emission and immunity level (and the associated limits) in one figure it is assumed that only one particular disturbance is considered, unless it is clearly indicated that different disturbances are considered and the relationship between the different disturbances is also indicated.

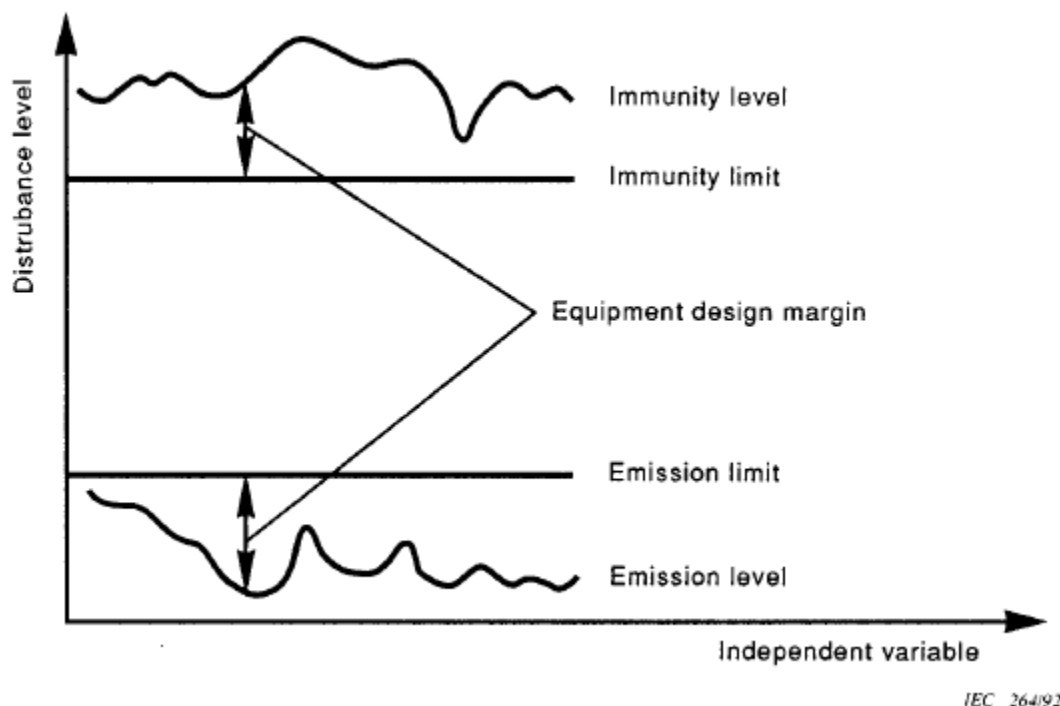



Figure 3 - Limits and levels for a single emitter and susceptor as a function of some independent variable (e.g., the frequency)

Consideration B

Drawing the emission and immunity level in one figure is only relevant when there is a good interrelation between the specified way the emission level of the particular

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disturbance is measured and the specified way that type of disturbance is incident on the equipment under test. If this is the case, Figure 3 indicates an electromagnetically compatible situation.

In Figure 3 there is some margin between a measured level and its limit. This margin might be called the "equipment design margin", and is an additional margin in the design to ensure compliance with the limit if EMC testing is carried out. Although it is an important consideration for manufacturers, this margin has not been defined in 2.1.1.1 (IEC 60050-161) nor in this specification, as equipment design issues are the prerogative of the manufacturer.

8.1.2.2 Compatibility level

Figure 4 shows the emission and the immunity limits of Figure 3, and a compatibility level in between these limits. The dashed lines indicate a possible emission and immunity level for a single emitter and susceptor. Again consideration A, presented in 8.1.2.1 'Emission and immunity level/limit', is valid.

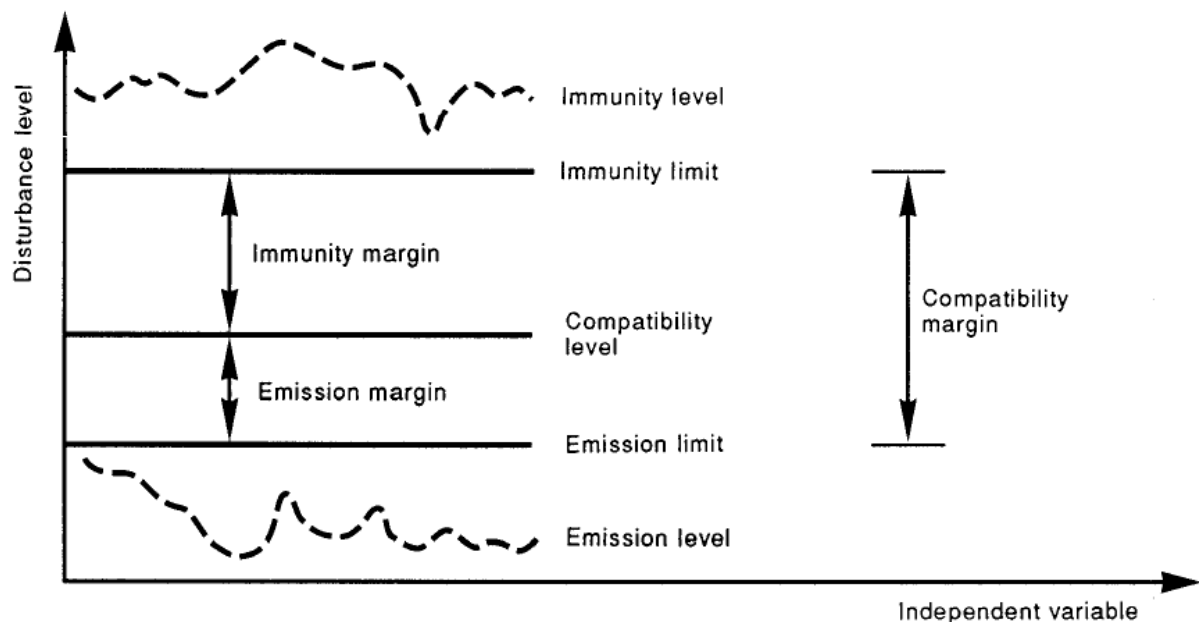


Figure 4 - Emission/immunity limits and compatibility level, with an example of emission/immunity levels for a *single* emitter and susceptor, as a function of some independent variable (e.g., the frequency)

The following additional considerations should be kept in mind:



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Consideration C

The compatibility level, being a specified disturbance level, is expressed in the unit corresponding to the emission limit. If the emission and immunity limits do not refer to the same disturbance, the compatibility level can be expressed in the unit corresponding to either the emission level or the immunity level.

Consideration D

If the electromagnetic environment is controllable, a compatibility level may be chosen first. Following this, emission and immunity limits are derived from this level in order to ensure an acceptable, high probability of EMC in that environment.

This consideration indicates that in a controllable environment, EMC can be achieved in the most cost-effective way by initially choosing the compatibility level on financial and technical grounds in order to realize appropriate emission and immunity limits for all equipment (to be) installed in that environment.

Consideration E

If the electromagnetic environment is uncontrollable, the level is chosen on the basis of existing or expected disturbance levels. However, emission and immunity limits have still to be assessed, to ensure that the existing or expected disturbance levels will not increase when new equipment is installed and that such equipment is sufficiently immune. If tests or calculations indicate that an existing situation has to be improved, because of the financial and technical consequences of the chosen limits, the compatibility level has to be adjusted and consequently, the emission and immunity limits. In the long run the adjusted compatibility level will then result in a more cost-effective solution for the total system.


Consideration F

The determination of limits from the compatibility level is governed by probability considerations, discussed in section 8.2. In general, these limits are not at equal distances from the compatibility level.

An example is given to illustrate the considerations in 8.1.2.1 and 8.1.2.2.

Example 1:

Assume an immunity limit has to be determined with regard to disturbances at the harmonics of the mains frequency, for equipment connected to the public low-voltage network. In addition, assume that for the equipment under consideration the mains network only serves as an energy supply (no mains signalling etc.). As this example is

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only an illustration of several aspects, the discussions will be limited to the odd harmonics.

The level of the harmonic disturbances in a public network is not readily controllable. Therefore the discussions start by taking the compatibility level U_c from 2.1.1.5 (IEC 61000-2-2). In IEC 61000-2-2 that level is given as a percentage of the rated voltage, and this approach is followed here (see Figure 5).

To ensure an acceptable, high probability of EMC, two requirements have to be met:

- a) At each frequency, the disturbance voltage level U_d in the network, i.e., the disturbance voltage resulting from all disturbance sources connected to that network, should have a high probability of fulfilling the relation $U_d < U_c$ at the locations where U_c is specified and for most of the time.
- b) At each frequency, there should be a high probability that the immunity level U_i of each appliance connected to the network fulfills the relation $U_i > U_d$.

The first requirement is largely met by taking the compatibility levels from IEC 61000-2-2.

Also given in Figure 5 is an emission limit of a single disturbance source. If it is known how many sources contribute to U_d and it is also known how the harmonic disturbances add, then an estimate can be made of U_d in that network. This is of interest in cases where the levels are controllable, because this estimate leads to a first choice of U_c for that particular network. Of course, the final choice is also determined by the immunity requirements.

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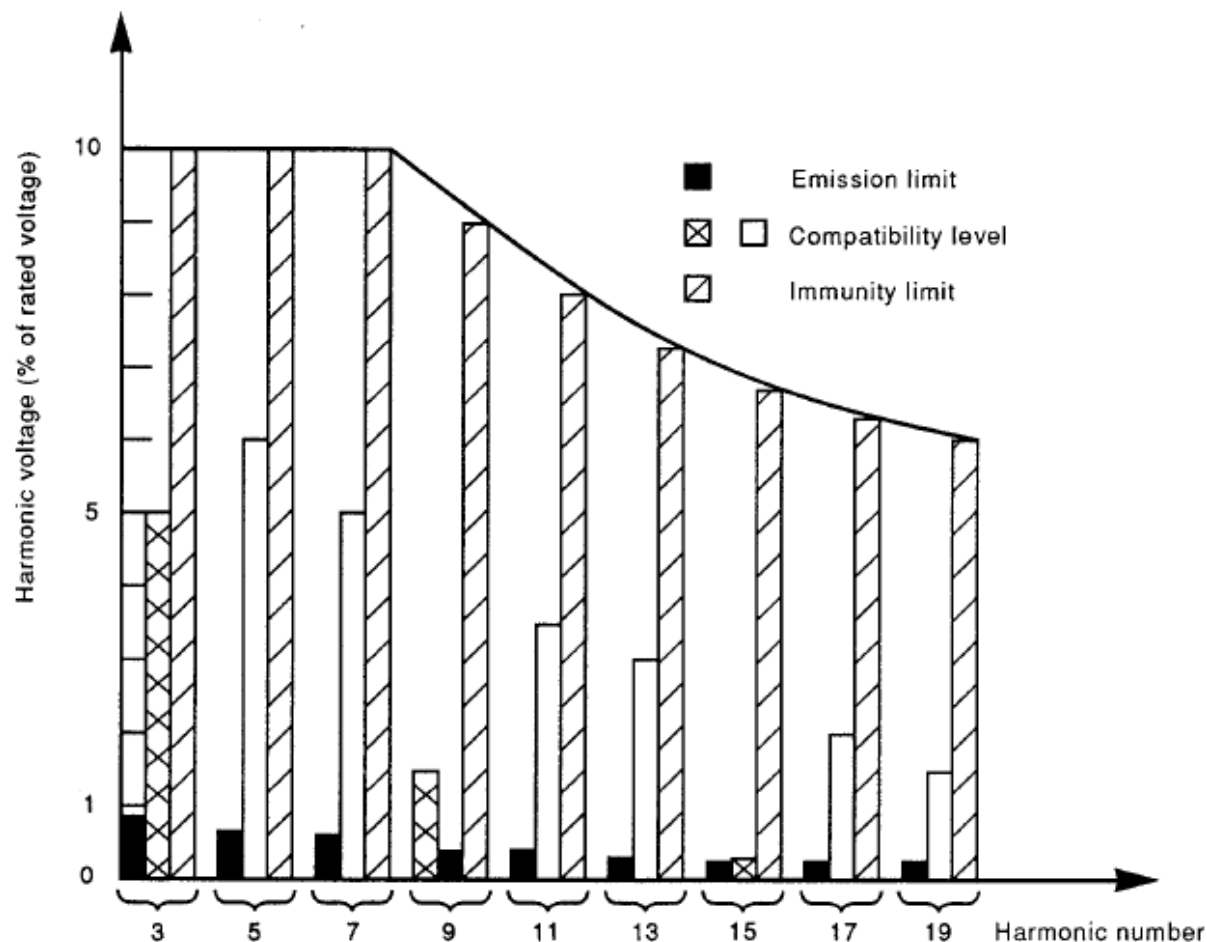



Figure 5 - Compatibility levels U_c for the odd harmonics in a public low-voltage network and examples of associated emission and immunity limits.

The emission limit is also given to illustrate a problem. In table 1 of IEC 61000-3-2 the emission limit for balanced three-phase equipment (so-called Class A equipment) is given as the maximum permissible harmonic current in amperes. However, the presentation in Figure 5 requires an emission limit expressed in a percentage of the rated voltage. The latter limit can be derived from the first limit when the network impedance is known. In this example it is simply assumed that this impedance is equal to the reference impedance at each harmonic frequency, that is, to $(0.4 + j n 0.25)$ ohm, n being the order of the harmonic (see IEC 555-2: 1982; canceled and replaced by IEC 61000-3-2: 1st edition 1995). In line with the above reasoning, the maximum harmonic voltage ratios given in annex A of IEC 555-2 are plotted in Figure 5. Note that in IEC 61000-2-2 a distinction is made between the odd harmonics that are a multiple of 3 and those that

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are not multiples of 3. In IEC 61000-3-2 this distinction is not made for the emission limit.

The actual disturbance level strongly depends on the number of disturbance sources, i.e., on the number of operating appliances connected to the network. In a public low-voltage network the number of sources that may contribute significantly is generally much larger at the low-frequency end than at the high-frequency end. Hence, the uncertainty about the actual disturbance level at lower frequencies is much greater than that at higher frequencies. This is reflected in Figure 5, where at the low-frequency end the distance between the emission limit (for a single device) and the compatibility level (which takes the superposition of disturbances into account) is much larger than the distance at the high-frequency end.


To meet the second requirement a sufficiently strict immunity limit is needed, of which an example is given in Figure 5. A distance between this limit and U_c , i.e., an immunity margin is needed because:

- 1) there is still a small probability that at a certain location and during a certain time interval the disturbance level will be above the compatibility level;
- 2) the internal impedance Z_i of the disturbance source used in the immunity test will not, in general, be equal to the internal impedance of the actual network. (A discussion about the value of Z_i to be used in the immunity test is beyond the scope of this Appendix.)

It is possible to specify a continuous immunity limit as illustrated in Figure 5. This has the advantage that the even harmonics, the inter-harmonics and all other disturbances in the given frequency range can be considered. A continuous function could be chosen as it was assumed at the beginning that the network served only as an energy supply, i.e., no mains signaling is present. For test purposes there may be a need to convert the percentages in which the immunity limit is given in Figure 5 to absolute values.

8.2 Compatibility level and margin (informative)

From the preceding sections of this Appendix it will be clear that it is often difficult, if not in fact impossible, to guarantee complete EMC, particularly because the definition of EMC refers to "its electromagnetic environment", which means the (time-dependent) totality of electromagnetic phenomena occurring at the location of that device. As explained in section 8.1, the concept of probabilities (statistical distributions) has to be used to arrive at an acceptably, high probability that electromagnetic compatibility will exist (for certain types of electromagnetic disturbances).

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The compatibility level and its margin, defined in sections 2.4.2 and 2.4.3, and already discussed in 8.1.2.2, might be determined along the following (idealized) lines.



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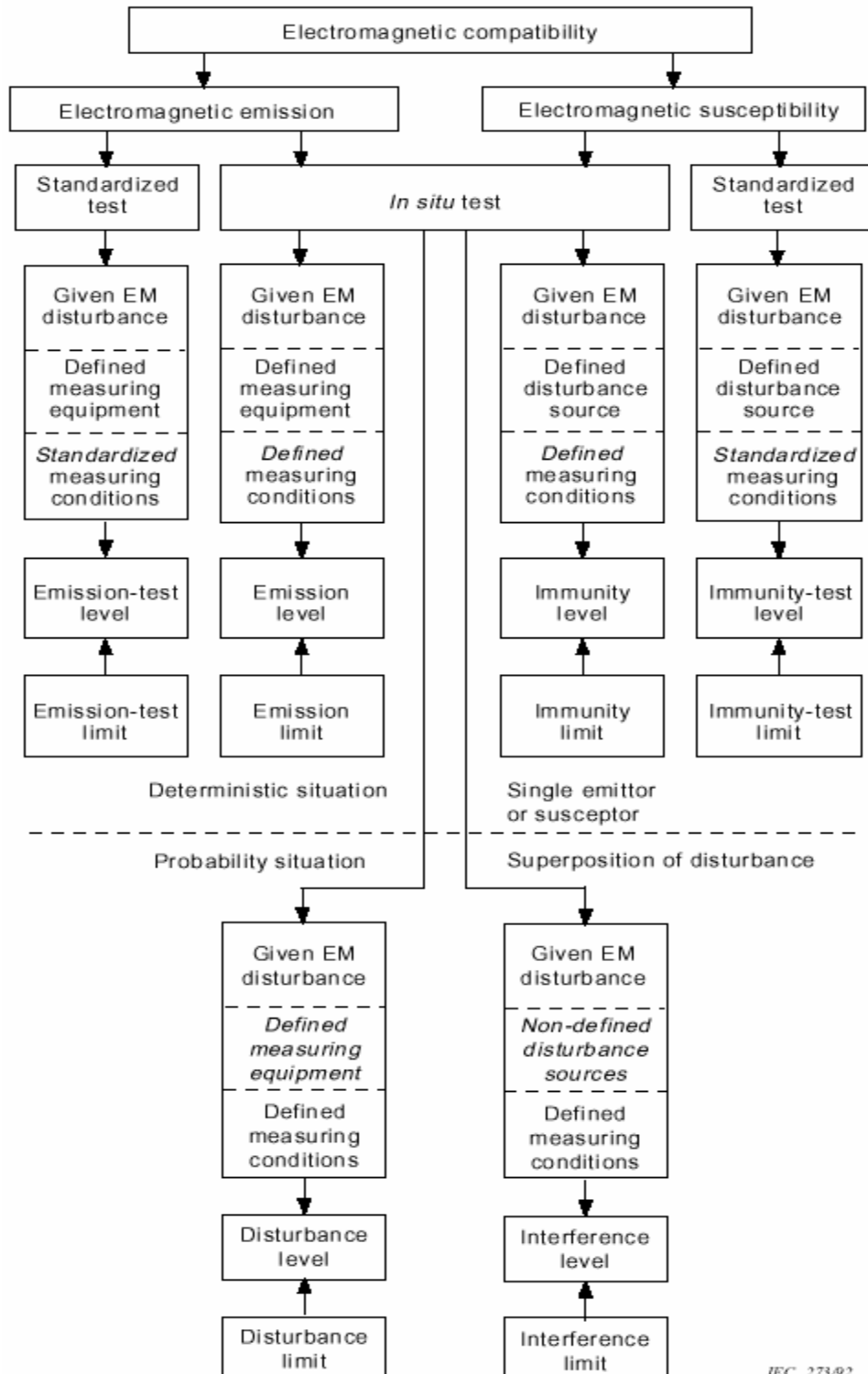


Figure 6 - Overview of various EMC terms and measuring conditions.

If one considers a certain type of electromagnetic disturbance, at a certain value of the independent variable and assumes that the associated probability densities $p(D)$ of the disturbance level and $p(I)$ of the immunity level are known. In addition, one may assume that the condition for EMC is given by $(I-D)>0$. To find the probability C that $(I-D)>0$, i.e., $C=P((I-D)>0)$, the probability density $p(I-D)$ is calculated first. After that the probability $C=P((I-D)>0)$ can be calculated, where C is the area under the curve $p(I-D)$ with $(I-D)>0$. Figure 7 gives a numerical example assuming log-normal distributions for the disturbance and susceptibility levels. It is concluded that there is a high probability of achieving EMC, in spite of the overlap of the curves $p(D)$ and $p(I)$.

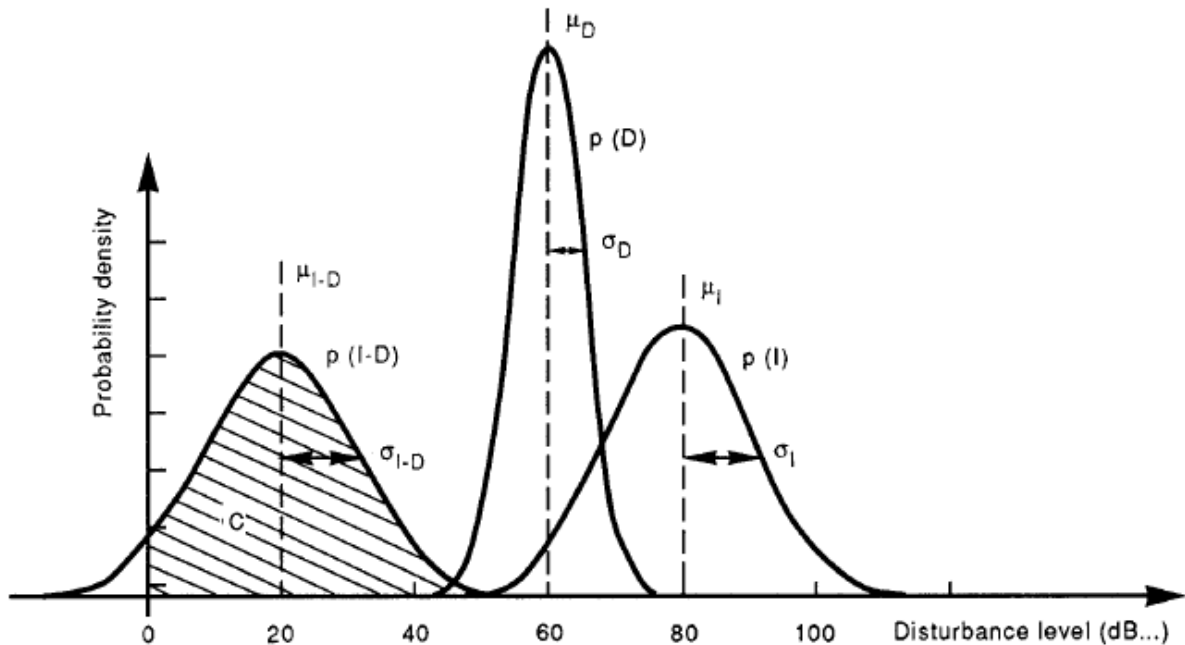



Figure 7 - Example of probability densities $p(D)$, $p(I)$ and the resulting $p(I-D)$. The area C under the curve $p(I-D)$ for values $(I-D)>0$ gives the probability of having EMC at the value of the independent variable under consideration

To achieve EMC, one can proceed as follows. After a certain value of C has been chosen, restrictions are imposed on the relative positions of $p(D)$ and $p(I)$, taking into account the width of the density functions. From the relation between $p(D)$ and the prescribed emission limit(s) and $p(I)$ and the prescribed immunity limit(s) then a value follows for the ratio of the emission and immunity limits, hence for the electromagnetic compatibility

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margin. Additional considerations of a financial and technical nature then lead to a choice of the compatibility level, the emission and immunity limits and the position of these limits relative to the compatibility level (see section 8.1.2.2). In the determination of the limits, the step has to be made from the "probabilistic situation" as determined by the possible actual situations to the "deterministic situation", associated with standardized tests.

The definition of compatibility level reads:

(Electromagnetic) compatibility level

The specified disturbance level at which an acceptable, high probability of electromagnetic compatibility should exist.

The following comments can be made.

- a) The definition uses "disturbance level", hence it is associated with a given electromagnetic disturbance measured in a specified way. In addition one could mention a disturbance compatibility level, for example a mains-harmonics compatibility level, a magnetic field compatibility level, etc.
- b) The level gives an indication of the probability of EMC, but only at the locations (in the system) where that level is specified, as the definition of EMC states "in its environment". Thus the level need not be valid worldwide. The choice of a level will very much depend on installation conditions.
- c) In the case a compatibility level is determined, a quantitative interpretation of "acceptable, high probability" is formulated by the IEC committee dealing with that compatibility level.

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