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IEC 1000-1-1 : 1992

Sri Lanka Standard
FOR ELECTROMAGNETIC COMPATIBILITY (EMC)
PART 1: General
Section 1 : Application and interpretation of fundamental definitions and terms

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SRI LANKA STANDARDS INSTITUTION

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Sri Lanka Standard
FOR ELECTROMAGNETIC COMPATIBILITY (EMC)
Part 1 : General
Section 1 : Application and interpretation of fundamental definitions and terms

NATIONAL FORWARD

This Sri Lanka Standard was authorized for adoption and publication by the council of the Sri Lanka Standard Institution on 1998-09-10.

This Standard is identical with IEC 1000-1-1, Electromagnetic compatibility (EMC) Part 1 : General. Section 1 : Application and interpretation of fundamental definitions and terms.

Terminology and conventions

The text of the international standard has been accepted as suitable for publication without deviation as Sri Lanka Standard. However, certain terminology and convertions are not identical with those used in Sri Lanka Standards, attention is therefore drawn to the following;

Wherever, the words "International standard" appears, referring to this standards they should be interpreted as "Sri Lanka Standard".

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RAPPORT TECHNIQUE
TECHNICAL REPORT

CEI
IEC
1000-1-1

Première édition
First edition
1992-04

Compatibilité électromagnétique (CEM)

Partie 1:
Généralités
Section 1: Application et interprétation de définitions et termes fondamentaux

Electromagnetic compatibility (EMC)

Part 1:
General
Section 1: Application and interpretation of fundamental definitions and terms

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- la CEI 417: *Symboles graphiques utilisables sur le matériel. Index, relevé et compilation des feuilles individuelles;*
- la CEI 617: *Symboles graphiques pour schémas;*

et pour les appareils électromédicaux,

- la CEI 878: *Symboles graphiques pour équipements électriques en pratique médicale.*

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- **IEC Bulletin**
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  Published yearly with regular updates

Terminology

For general terminology, readers are referred to IEC 50: *International Electrotechnical Vocabulary (IEV),* which is issued in the form of separate chapters each dealing with a specific field. Full details of the IEV will be supplied on request. See also the IEC Multilingual Dictionary.

The terms and definitions contained in the present publication have either been taken from the IEV or have been specifically approved for the purpose of this publication.

Graphical and letter symbols

For graphical symbols, and letter symbols and signs approved by the IEC for general use, readers are referred to publications:

- IEC 27: *Letter symbols to be used in electrical technology;*
- IEC 417: *Graphical symbols for use on equipment. Index, survey and compilation of the single sheets;*
- IEC 617: *Graphical symbols for diagrams*;

and for medical electrical equipment,

- IEC 878: *Graphical symbols for electromedical equipment in medical practice.*

The symbols and signs contained in the present publication have either been taken from IEC 27, IEC 417, IEC 617 and/or IEC 878, or have been specifically approved for the purpose of this publication.

IEC publications prepared by the same technical committee

The attention of readers is drawn to the end pages of this publication which list the IEC publications issued by the technical committee which has prepared the present publication.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC)

Part 1: General

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FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

This Report has been prepared by IEC Technical Committee No. 77: Electromagnetic compatibility between electrical equipment including networks.

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

Six Months' Rule	Report on Voting
77(CO)37	77(CO)38

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

INTRODUCTION

IEC 1000 is published in separate parts according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

Immunity limits (in so far as they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 9: Miscellaneous

Each part is further subdivided into sections which can be published either as International Standards or Technical Reports.

These standards and reports will be published in chronological order.

This section is identified by ACEC as a basic EMC publication.

ELECTROMAGNETIC COMPATIBILITY (EMC)

Part 1: General

Section 1: Application and interpretation of fundamental definitions and terms

1 Scope

The object of this report is to describe and interpret various terms considered to be of basic importance to concepts and practical application in the design and evaluation of electromagnetically compatible systems. In addition, attention is drawn to the distinction between electromagnetic compatibility (EMC) tests carried out in a standardized set-up and those carried out at the location where a device (equipment or system) is installed (*in situ* tests).

The terms and their definitions are given in clause 2, with reference to chapter 161 of the IEV [1]. The application of the terms is described in clause 3 and an interpretation of their definitions is presented in the annexes.

2 Definition of terms

The terms of importance in the context of this report are defined below. Each definition is followed by its IEV number when it is identical with the definition (and any note accompanying it) given in [1]*. Where it differs, the IEV number is followed by "/A", or it is indicated that the term has not been defined in IEC 50(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.

2.1 *Basic terms*

electromagnetic environment (161-01-01): The totality of electromagnetic phenomena existing at a given location.

Note/A: In general, this totality 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.

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* The figures in square brackets indicate the references listed in page 64.

electromagnetic interference; EMI (abbreviation) (161-01-06): Degradation of the performance of a device, equipment or system caused by an electromagnetic disturbance.

Note/A: Disturbance and interference are cause and effect respectively.

NOTES

1 The English words "interference" and "disturbance" are often used indiscriminately.

2 In French, the term "perturbation électromagnétique" is also used with the meaning of "brouillage électromagnétique".

3 In Russian, the terms "vozmuscenie" and "pomeha" are often used with the same meaning.

electromagnetic compatibility; EMC (abbreviation) (161-01-07): 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 quantity) (not defined in IEC 50(161): The magnitude of a quantity evaluated in a specified manner.

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

2.2 *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, measured in a specified way.

emission limit (from a disturbing source) (161-03-12/A): The maximum permissible emission level.

immunity level (161-03-14/A): 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.

immunity limit (161-03-15/A): The minimum required immunity level.

disturbance level (not defined in IEC 50(161): The level of a given electromagnetic disturbance, measured in a specified way.

(electromagnetic) compatibility level (161-03-10/A): The specified disturbance level at which an acceptable, high probability of electromagnetic compatibility should exist.

2.3 *Interrelated terms*

emission margin (161-03-13/A): The ratio of the electromagnetic compatibility level to the emission limit.

immunity margin (161-03-16/A): 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/A: 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".

3 Application of EMC terms and definitions

3.1 *General*

The definitions given in clause 2 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. For an interpretation of the various terms used, see annexes A and B.

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.

3.2 *Relation between various levels*

3.2.1 *Emission and immunity level/limit*

Figure 1 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 1 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 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 example 1 in 3.2.2.

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.

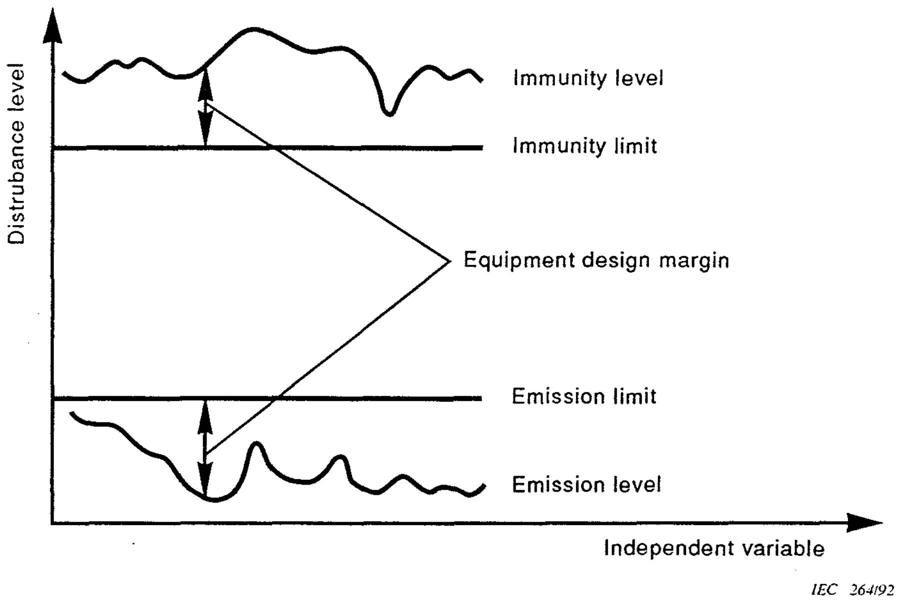

Figure 1 – Limits and levels for a single emitter and susceptor as a function of some independent variable (e.g. the frequency)

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 disturbance is measured and the specified way that type of disturbance is incident on the equipment under test. If this is the case, figure 1 indicates an electromagnetically compatible situation.

In figure 1 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 IEC 50(161) [1] nor in this report, as equipment design issues are the prerogative of the manufacturer.

3.2.2 *Compatibility level*

Figure 2 shows the emission and the immunity limits of figure 1, 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 3.2.1, is valid.

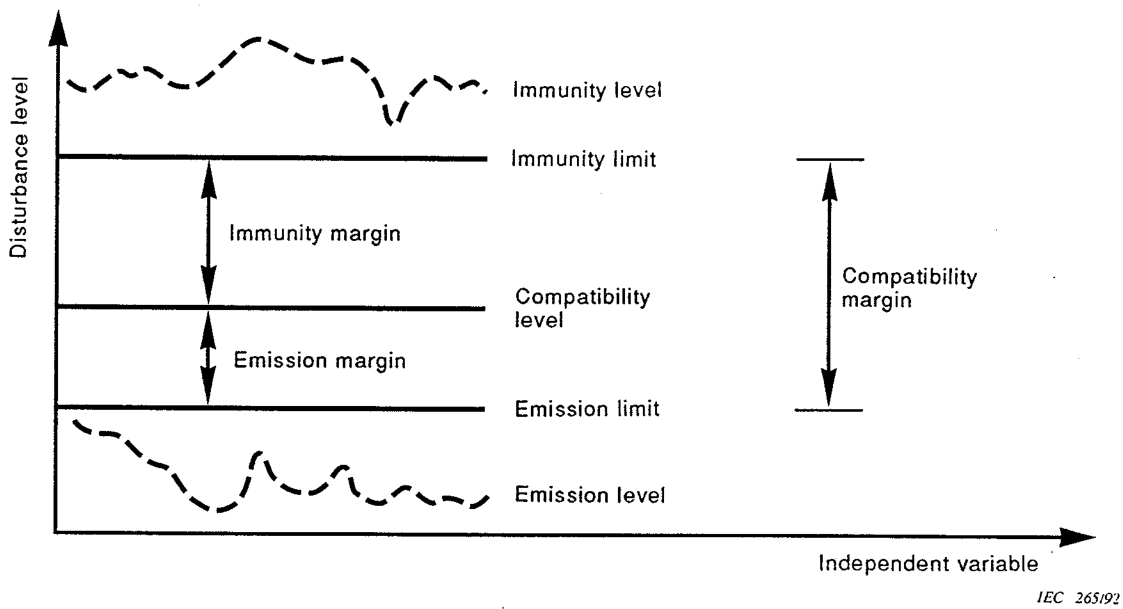

Figure 2 – Emission/immunity limits and compatibility level, with an example of emission/immunity levels for a *single* emitter and susceptor, as a function of some independent variable (e.g. the frequency)

The following additional considerations should be kept in mind:

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 (see example 2 below), 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 3.3. In general, these limits are not at equal distances from the compatibility level, see also 3.3. In clause 6 of annex A the compatibility level is determined for an idealized situation, where the probability density functions are assumed to be known.

Two examples are given to illustrate several considerations in 3.2.1 and 3.2.2.

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 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]. In [2] that level is given as a percentage of the rated voltage, and this approach is followed here (see figure 3).

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 [2].

Also given in figure 3 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.

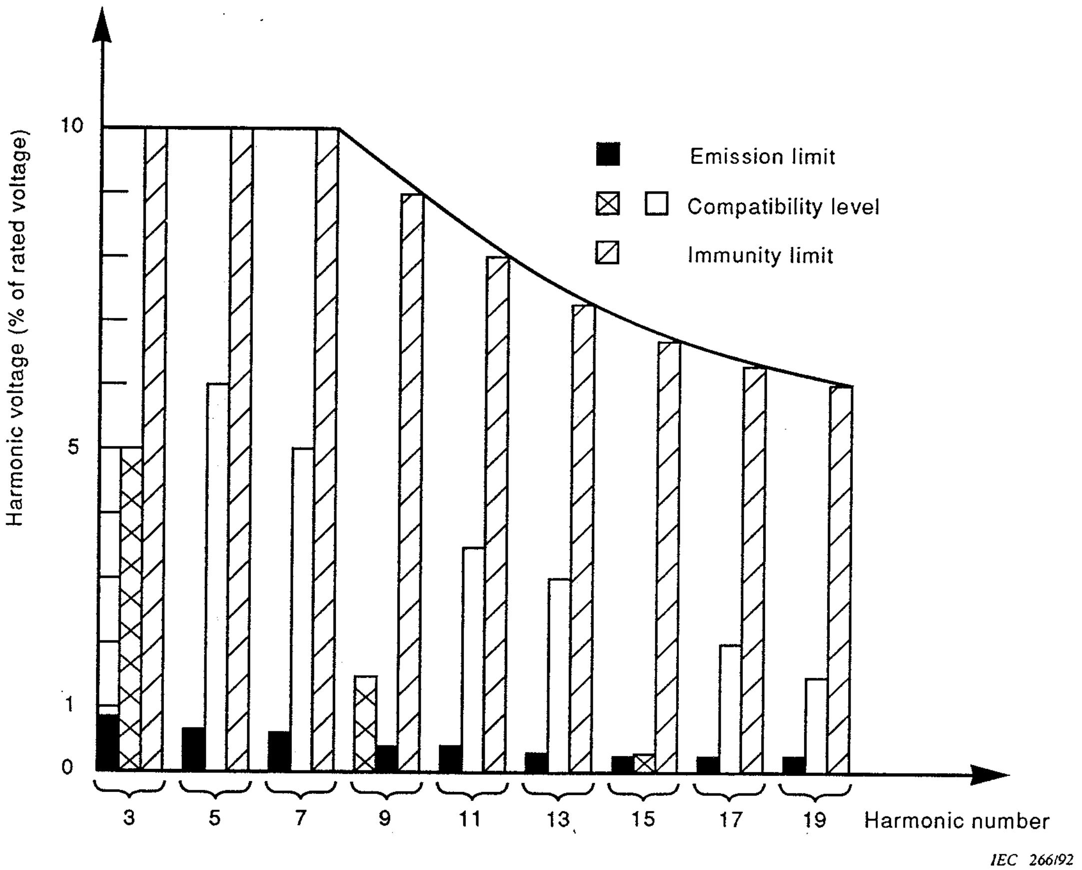

Figure 3 – Compatibility levels U_c for the odd harmonics in a public low-voltage network and examples of associated emission and immunity limits.

The emission limit is also given to illustrate a problem. In table 1 of [3] the emission limit is given as the maximum permissible harmonic current in amperes. However, the presentation in figure 3 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, given in [3]. In line with the above reasoning, the maximum harmonic voltage ratios given in annex A of [3] are plotted in figure 3. Note that in [2] a distinction is made between the odd harmonics that are a multiple of 3 and those that are not multiples of 3. In [3] 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 3, 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. This distance, i.e. the emission margin, will be discussed in 3.3.

To meet the second requirement a sufficiently strict immunity limit is needed, of which an example is given in figure 3. A distance between this limit and U_c, i.e. an immunity margin (see 3.3), 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 report.)

It is possible to specify a continuous immunity limit as illustrated in figure 3. 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 signalling is present. For test purposes there may be a need to convert the percentages in which the immunity limit is given in figure 3 to absolute values.

Example 2:

There are cases where emission, compatibility and immunity levels and limits may be expressed in different units.

Consider the immunity to RF fields of equipment having dimensions small compared to the wavelength of that RF field. It is well known that the equipment immunity is determined largely by the immunity to common-mode currents induced in the leads connected to that equipment [4]. Hence, the interrelated radiated and conducted phenomena have to be taken into consideration when attempting to achieve EMC.

With regard to 3.2.1, as the relationship between the field strength and the e.m.f. has been established in other studies, it is possible to express the emission level in figure 1 as an electric field strength (for example in dB (μV/m)) and the immunity level as the e.m.f. (for example in dB (μV)) of a disturbing source, e.g. a test generator.

With regard to figure 2 and the foregoing considerations, the compatibility level may now be expressed in dB (μV/m) or in dB (μV). It is clear that this level depends on the chosen unit. In addition, the choice of the compatibility level may also be determined by the susceptibility properties of the susceptor concerned. If the EMI problem to be prevented concerns RF-field demodulation, the degradation is (in first order approximation) proportional to the square of the RF disturbance level. Hence, the immunity margin may be chosen to be larger than the emission margin (see 3.3).

3.3 *Probability aspects and margins*

If the emission and immunity tests have been designed in such a way that there is a good correlation with the electromagnetic phenomena existing, the situation in figure 4 may represent an electromagnetically compatible situation for the single emitter and susceptor under consideration.

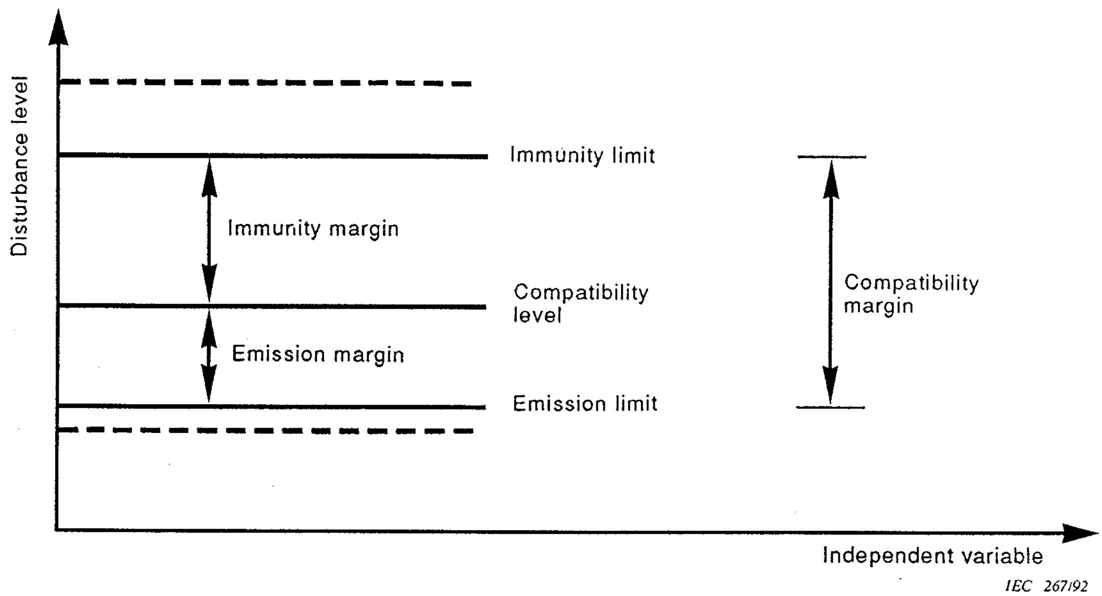

Figure 4 – Limits, compatibility level and margins, as a function of any independent variable (for example the frequency)

Indeed, figure 4 indicates that the immunity level is higher than the immunity limit and this is higher than the emission limit which, in turn, is higher than the emission level. However, the situation depicted in figure 4 does not guarantee that EMC will exist in the actual situation, as there are uncertainties, already briefly mentioned in the first example in 3.2.2.

The existence of these uncertainties means that after the compatibility level has been chosen, margins are required between that level and the emission and immunity limits to be prescribed. In figure 4, the margins, defined in 2.3, are shown as solid lines. The dashed lines refer to the equipment design margin, to be chosen by the manufacturer and already discussed in 3.2.1. Four important uncertainties will be discussed in the next subclauses.

3.3.1 *Standardized test*

In the case of a standardized test, see annex B, there are two important uncertainties which influence the magnitude of the margins between compatibility level and the prescribed limits:

1) the relevance of the test method, and

2) the normal spread of component characteristics in the case of quantity-produced equipment.

Uncertainty 1: The relevance of the test methods

Standardized test methods in particular endeavour, with a very limited number of test situations, to cover an almost infinitely large number of actual situations in which equipment has to function satisfactorily. Hence, the relevance of the test method is determined by the extent to which the method covers an actual situation, and this is known only to a limited extent.

A standardized emission test is always carried out by using a well-defined measuring device (voltage probe, antenna, etc.) connected to well-defined measuring equipment, instead of using an actual susceptor. Similarly, in standardized immunity tests the emitter is a well-defined generator with a well-defined coupling device, and not an actual emitter. Nevertheless, these emission and immunity tests are carried out to achieve EMC at the locations where the actual emitters and susceptors interact.

In general, standardized tests consider only one phenomenon at a time, for example emission via conduction or emission via radiation. A similar remark applies to immunity testing. However, in the actual situation all phenomena act simultaneously, and this reduces the relevance of a standardized test.

As a consequence of the limited relevance of a standardized test, margins are needed between compatibility level and the emission and immunity limits.

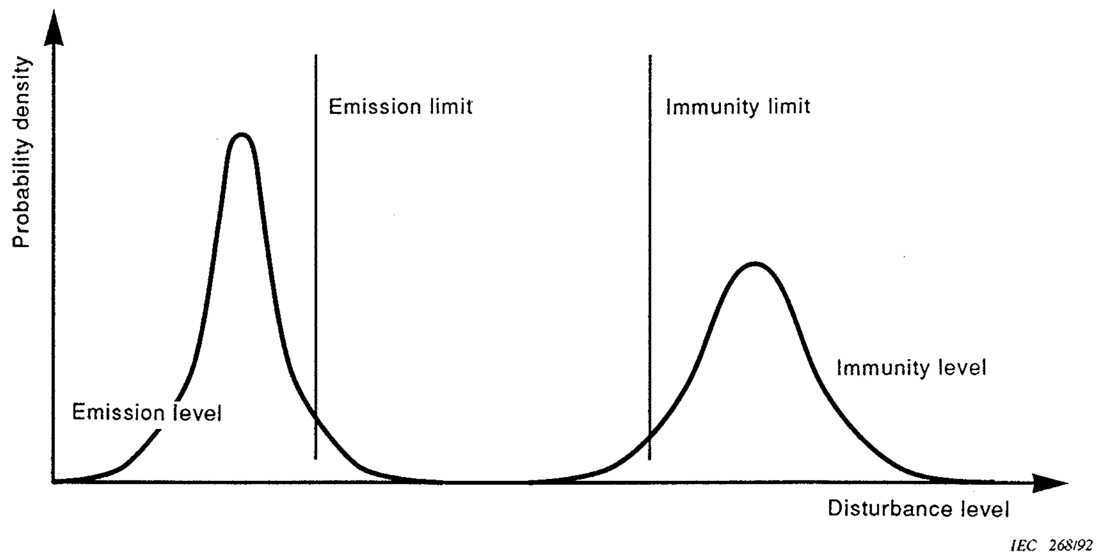

Figure 5 – Example of the probability densities for an emission level and an immunity level, at one single value of the independent variable

Uncertainty 2: Normal spread of component characteristics

Not all devices, equipment or systems, especially those that are quantity-produced, will be tested before installation. If all equipment were tested, test-data distributions would be found, as a consequence of the spread of component characteristics. This is illustrated in figure 5. Hence, there is an uncertainty as to whether a randomly chosen equipment from that quantity-production will comply with the limit. This uncertainty is considered in detail in clause 9 of [5], the part on the so-called "80 %–80 % compliance rule". The distributions are also determined by the reproducibility of the test method.

It should be noted that curves similar to those given in figure 5 will be found for each value of the independent variable in the prescribed EMC test. Hence, figure 5 can only apply to the test data for one single value of the independent variable.

From figure 5 it can be concluded that there is a very small probability that an equipment will not comply with the limit, and because of the chosen compatibility margin the probability that an EMI problem will result in this case is negligible. Figure 5 also shows that the manufacturer had chosen a certain equipment design margin. In some cases, see for example [5], [6], the 80%-80% compliance rule creates the need for a minimum equipment design margin, where this margin depends on the EMC test sample size.

3.3.2 In situ *test, superposition*

In addition to the two uncertainties mentioned in 3.3.1, the superposition of disturbances produced by various sources in the installation gives rise to an uncertainty.

This uncertainty relates to the relevance of the test, and it should be noted that an *in situ* test, i.e. a test at the location where the equipment under test is in use, is not as well defined as the standardized test; see annex B. In particular the load impedance of an emitter is often unknown and often time-dependent. For example, the differential-mode mains impedance depends, among other things, on equipment (switched on or switched off) connected to the network. A similar remark applies when immunity is considered. As a result, the margins chosen in the installation may differ from those in the standardized test.

Uncertainty 3: Superposition effects, multidimensional criteria

At the location of the susceptor the electromagnetic environment is determined by *all* devices, equipment and systems emitting electromagnetic energy. Hence, many types of disturbances ("type" also includes the wave-form, e.g. sinusoidal, pulsed) may be present simultaneously. If a given disturbance is considered at a given location, the disturbance level is determined by:

a) the superposition of disturbances of the same type, where each disturbance contribution depends on the loading conditions of its emitter, on the electromagnetic propagation properties between that emitter and the susceptor, and on time;

b) contributions of other types of disturbances, having components in the susceptor reception band, where each of the contributions is subject to the aspects mentioned above under a).

The uncertainty of the actual value of the ultimate disturbance level, creates the need for margins.

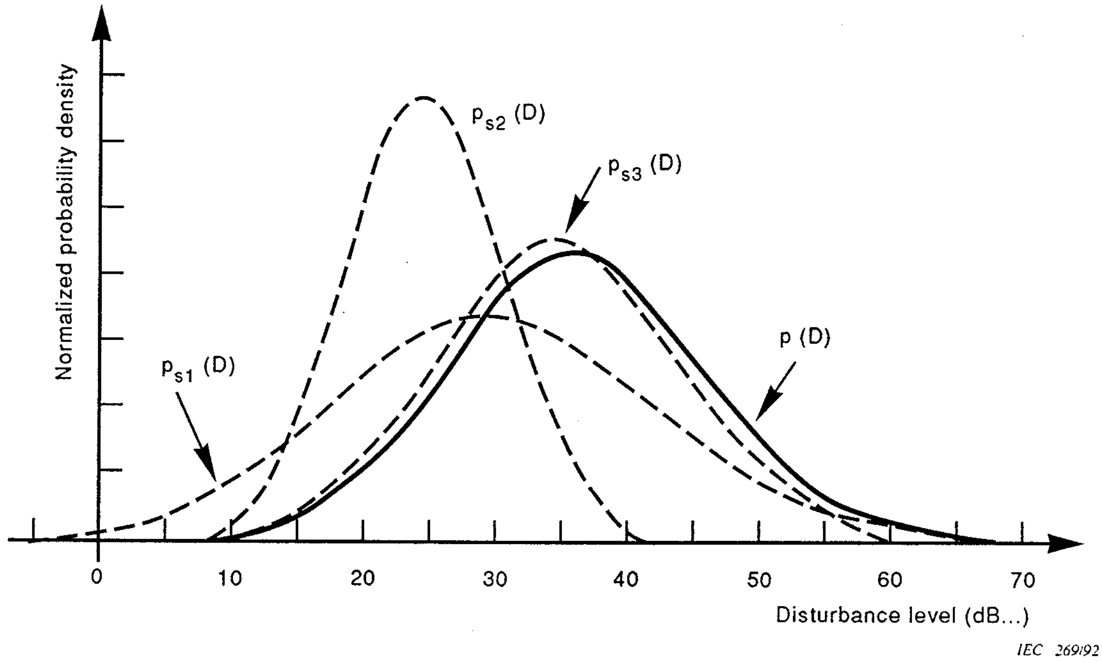

Figure 6 – Example of superposition of disturbances. The ultimate disturbance level probability density, p(D), originates from the probability densities $p_s(D)$ of various types of sources

Example:

An example of the superposition of disturbances, mentioned under a), is given in figure 6. In this example it is assumed that there are three types of emitters emitting the same type of disturbance. As with figure 5, it is only possible to consider the results for one value of the independent variable at a time. The three associated probability density functions are represented by $p_{si}(D)$ (i = 1, 2, 3). In this example the ultimate density function p(D) is largely determined by $p_{s3}(D)$. Note that, in general, the density function will be time dependent, as it depends on the number of sources which are operating.

Gaussian distributions have been used in the examples in this text, other types of distributions are also possible.

The ultimate disturbance level is of importance to *all* possible susceptors at a particular location (in a particular system), where each type of susceptor will have its specific immunity properties (see figure 7) even if these types have to comply with the same immunity limit. In addition, at the location where the device, equipment or system is installed various types of disturbances might enter the susceptor simultaneously, and this is another type of superposition. The immunity level for one type of disturbance may be negatively influenced by the presence of another type of disturbance (see annex B). Consequently, there is an additional need for additional margins.

3.3.3 *Lack of data*

Uncertainty 4: Lack of data

Generally, there is no time, or it is impossible, to measure the disturbance levels at all possible locations where a susceptor may be installed, and therefore the disturbance probability density given in figure 7 is seldom known. Furthermore, the immunity level distribution is often unknown. The latter is the case when exceeding the immunity level results in a (high) risk of damage to the susceptor and the immunity is tested in a "go – no go" test, to an electromagnetic disturbance level equal to (or an agreed amount higher than) the minimum required immunity level, i.e. the immunity limit. This lack of supporting data again creates the need for margins between the compatibility level and the limits to be prescribed.

In some cases the lack of certain disturbance source data can be of importance if equipment, which operated initially in dedicated environments, then becomes widely used. For example, much is known about the mains at the fundamental frequency and its harmonics and about the associated impedances, where differential-mode conducted disturbances are concerned. Much less is known about the magnetic fields produced by these disturbances in actual situations. These fields are now of great importance in view of the increased use of video display units and electron microscopes (in high-technology industries), as these fields may strongly influence the deflection of the electron beam in such equipment. (Moreover, it is not possible to shield low frequency magnetic fields in a cost-effective way.)

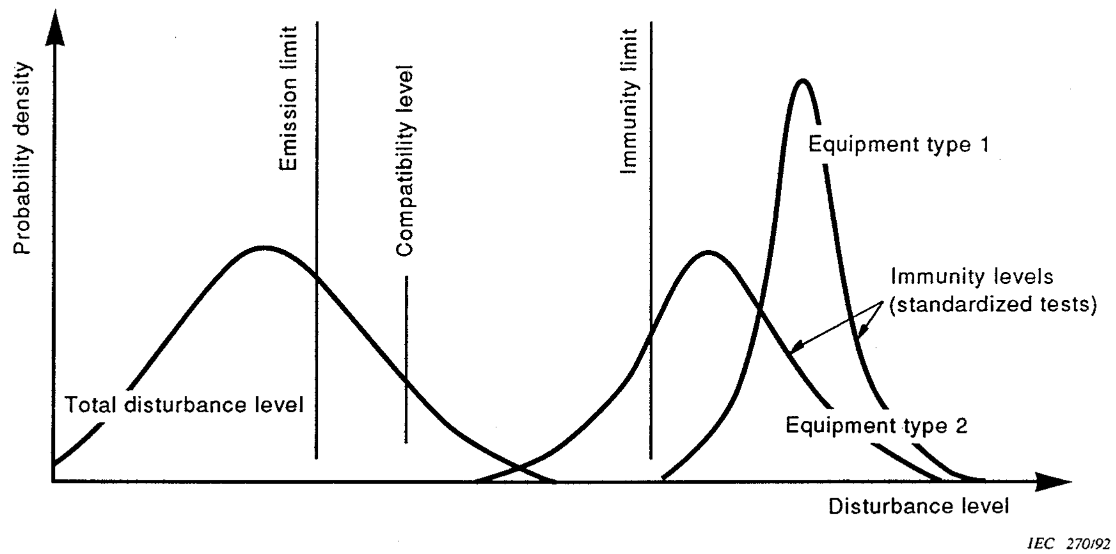

Figure 7 – Example of probability densities for an ultimate disturbance level (the sum of disturbance levels produced by various emitters) and the immunity levels of two types of susceptor

Annex A

Interpretation of EMC terms and definitions

A.1 General

In this section terms and definitions given in clause 2 are discussed to give background information about the chosen definition and the consequences of using the terms in the description of EMC requirements.

A.2 Electromagnetic interference, compatibility and environment

The ever increasing number of applications of electrical and electronic equipment also gives rise to an increasing number of operational difficulties. One of the factors contributing to these operational difficulties is that devices in use are found to interfere with each other as a result of the electromagnetic properties of the devices (equipment, or systems) involved. If all these devices could exist side by side in harmony the world would be electromagnetically compatible. Unfortunately, this situation has not become universal and electromagnetic interference problems have to be solved.

In an electromagnetically compatible situation the electromagnetic environment is such that everything in it is in harmony.

A.2.1 *Electromagnetic interference (EMI)*

The existence of EMI makes it necessary to consider EMC, so the definition of EMI is considered first.

> *Electromagnetic interference; EMI* (abbreviation)
>
> Degradation of the performance of a device, equipment or system caused by an electromagnetic disturbance.

The electromagnetic disturbance mentioned in this definition has been defined as

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

The following observations can be made:

a) *Interference/disturbance*

The English words "interference" and "disturbance" are often used indiscriminately. However, it should be noted that "interference" refers to the unwanted degradation, and "disturbance" refers to the electromagnetic phenomenon causing that degradation.

Consequently, if that phenomenon is described in terms of a measurable quantity, for example a voltage, it shall be called disturbance voltage, and not interference voltage ([1], section 161-4]).

b) *Elementary form of EMI problem*

The definition of EMI refers to "degradation of the performance ..... caused by ....". This means that, in its elementary form, an EMI problem consists of three ingredients (see figure A.1), namely:

1) an emitter, i.e. a source emitting the electromagnetic disturbance,

2) a susceptor, i.e. a susceptible device, equipment or system showing degradation of its performance,

3) a medium in between, which is called the coupling path.

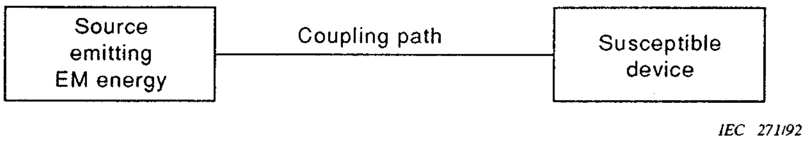

Figure A.1 – The basic form of an EMI problem

Hence, EMI problems have two key aspects: emission *and* susceptibility, and it will be shown later that EMC also possesses these two key aspects.

c) *Degradation*

The definition of the term degradation is as follows:

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

It is important to note that the adjective "undesired" is used and not, for example, the adjective "any". This aspect is very important when setting down EMC specifications. The kind of departure in the operational performance which is considered to be undesired must be made clear in these specifications.

Example:

Assume a computing system has to function without degradation in the presence of certain types of interruptions in the mains voltage of that system. Errors in the computation caused by these interruptions always form an undesired departure. If the degradation can be avoided by using a battery-backup, it will be found that the interruptions cause a slight increase in the computation time because the system has to switch from mains to battery and vice versa. In many cases this departure is fully acceptable.

A.2.2 *Electromagnetic compatibility (EMC)*

At the beginning of A.2 it is stated that: "If all devices could exist side by side in harmony, the world would be electromagnetically compatible (EMC)". In an electromagnetically compatible situation the electromagnetic environment is such that everything in it is in harmony. The addition of a device to that environment without causing EMI then means that this device has the property of being electromagnetically compatible. Thus, the definition of EMC reads:

Electromagnetic compatibility; EMC

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

The desired harmony comes to the fore in two important ways, which are the two key aspects of EMC:

1) "to function satisfactorily", means that the device (equipment or system) is "tolerant of others", i.e. the device (equipment or system) is not susceptible to disturbances present in its environment.

2) "without introducing intolerable disturbances", means that the device "gives no offence to others", i.e. the emission of the device (equipment or system) does not result in electromagnetic interference.

The key aspects emission *and* susceptibility, already found for EMI, are also the key aspects of EMC. This is illustrated in figure A.2, which represents the beginning of a subdivision to be completed in figure A.3.

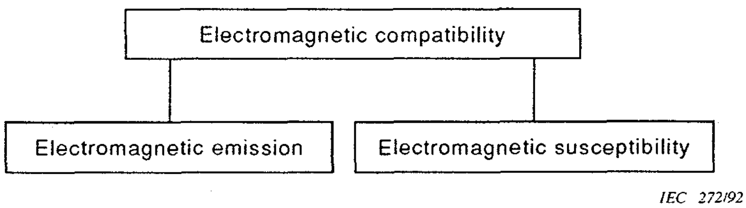

Figure A.2 – Subdivision of EMC in its key aspects

A.2.3 *The electromagnetic environment*

In real life situations there are normally many sources (man-made and natural) emitting electromagnetic disturbances, creating an electromagnetic environment in which possible susceptors reside. The diversity of situations is immense and a complete description of the electromagnetic environment is very complex.

Normally the environment has to be determined (estimated) by separately measuring (calculating) certain parameters of the electromagnetic phenomena, such as voltages, currents, fields, etc., at the locations involved. In most cases it is found that these quantities vary in time. Therefore, the electromagnetic environment, used in the definition of EMC, is defined as

Electromagnetic environment

The totality of electromagnetic phenomena existing at a given location.

NOTE - In general, this totality is time dependent and its description may need a statistical approach.

The following observations can be made with regard to the use of the term electromagnetic environment in the definition of EMC.

a) *Its environment*

The definition of EMC refers to *its* environment and not to "an" environment or "every" environment. This means that if a device has the property of being electromagnetically compatible in a particular environment it does not necessarily mean that it will be electromagnetically compatible in another environment. In most cases the properties of the electromagnetic environment are never 100 % predictable, because they are location- and time-dependent. This implies that EMC specifications can only be written in such a way that there is an agreed or acceptable probability that the device is electromagnetically compatible in certain environments.

b) *Anything in that environment*

The definition of EMC refers to "anything in that environment". This means that, in addition to devices, equipment and systems, living creatures could also be involved. This aspect is of importance when emission limits are set to electromagnetic fields, to achieve EMC.

Example:

Consider the electromagnetic field produced by large RF-heating equipment in situations where it is known that the distance between the RF equipment and possibly susceptible devices is large and some building attenuation is experienced. One may then decide on a limit which is acceptable to those devices. However, the operator working inside the building at very short distances from the RF equipment might then be exposed to intolerable fields, as a consequence of the variation of the field strength with the distance from the source.

A.3 Susceptibility/immunity

As susceptibility is one of the two key aspects of both EMC and EMI the definition of susceptibility is a broad definition and reads as follows:

Susceptibility

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

The opposite of the concept susceptibility is immunity. The definition of immunity reads:

Immunity

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

It can readily be seen that the definitions of immunity and susceptibility differ by one single word: where "ability" is used in the definition of immunity, "inability" is found in that of susceptibility. The question may arise as to whether, if the definitions differ only by one word, it is sensible to delete one of the terms and, if so, which term. The answer must be "No", for the following reasons.

As pointed out in clause A.2, the need to consider the EMC of devices is the existence of EMI, hence the existence of susceptible devices. In general, it will always be possible to find an electromagnetic disturbance causing degradation of the device performance. So one has to consider EMC since susceptibility is a *basic property* of almost every device. This is also indicated in IEC 50(161), where the note accompanying the definition of susceptibility states that susceptibility is a "lack of immunity" [1]. Thus a name is required for this basic property. Of course this might be called "a lack of immunity", but it is more sensible to choose one single word: susceptibility.

But, the ultimate goal is to achieve an electromagnetically compatible world. Hence, immune devices, equipment and systems are very much needed. Therefore, the term immunity is the relevant term to be used in EMC specifications. In general, immunity is achieved by taking preventive or corrective measures. It should be noted that an immunity requirement is always specified for a given type of electromagnetic disturbance which is incident in a specified way; see also A.5.

A.4 Level and limit

When setting EMC specifications, specific values have to be assigned to the levels of electromagnetic disturbances in the particular cases. The definition of level reads [7]:

> *Level* (of a quantity)
>
> The magnitude of a quantity evaluated in a specified manner.

The definition of electromagnetic disturbance reads:

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

If a quantity has to be evaluated in a specified way, it has to be known which quantity is meant. Consequently, the definition of a disturbance level has to reflect this requirement, so it is defined:

> *Electromagnetic disturbance level*
>
> The level of a given electromagnetic disturbance, measured in a specified way.

The adjective "given" is also found in other level definitions, such as "emission level", "susceptibility level", etc.

Strictly speaking, it could be said that the addition of "measured in a specified way" is not necessary, for the definition of "level" refers to "evaluated in a specified manner". However, there is the risk that the "specified way" could be applied only to the measuring device and its indicating instrument. The phrase "measured in a specified way" implies a specification of the loading conditions of the disturbance source and a detailed description of the test configuration, which can be summarized as follows:

Evaluated/measured in a specified manner/way

The *measuring device* shall be well defined and chosen having regard to the type of disturbance to be measured, and to the properties of desired signals which might be affected by the emission measurement.

The *measuring equipment* shall be well defined and chosen having regard to the type of disturbance and associated properties to be determined. Examples of disturbance properties are: peak amplitude, energy, rate of rise, repetition rate, etc.

The *loading conditions* of the disturbance source shall be described. A measuring set-up will present certain load impedances to the disturbance source(s) in the equipment under test (EUT). These impedances may be standardized, for example in type tests, or may depend on the conditions at the place of installation, for example in the case of *in situ* tests (see also annex B).

The *test configuration* has to be described in detail. This description should consider the choice of the reference (ground), the position of the EUT and measuring equipment with respect to that reference, connections to that reference, interconnections of the EUT with the measuring device and other equipment, termination of terminals which are not connected to the measuring device, and operating conditions of the EUT during testing. In addition it may be necessary to describe the disposition of system components and configurations for maximizing the emission level, cable lengths, decoupling of system components.

Once a level has been determined, an evaluation of that level has to be made: is it permissible or not? is it what has been required or not? etc. When setting EMC specifications the parties involved can agree on an acceptable level, which then is called a limit. In the case of an electromagnetic disturbance the definition of disturbance limit is as follows:

Disturbance limit

The maximum permissible electromagnetic disturbance level.

Note that the inclusion of electromagnetic disturbance level in this definition implies that the limit is specified for a *given* electromagnetic disturbance, measured *in a specified way.* This also applies to other limit definitions, such as "emission limit" and "immunity limit".

A.5 Emission and immunity

As emission is one of the two key aspects of EMC and EMI, its definition is rather broad and reads:

(Electromagnetic) emission

The phenomenon by which electromagnetic energy emanates from a source.

In this definition the source normally is a device, equipment or system, but it can, for example, also be a human being or a piece of furniture. The two last named "sources" are of importance when considering electrostatic discharge phenomena. An example of a natural source is lightning.

In general, the emission will be determined in order to prevent EMI. However, a difficult question is: "What is the relevant parameter of the electromagnetic energy to be determined, and how shall it be determined?" The problem is that there is seldom exact knowledge of the susceptibility properties of devices, equipment and systems. In other words: it is seldom known precisely how such an item exactly "measures and detects" the emission and, strictly speaking, it is not known what has to be measured.

Experience has shown that it is necessary to measure certain types of emission. But, in fact, all these measurements are no more than an attempt to replace possible susceptible devices by well-defined measuring devices in a defined measuring method. As a result a determination of the emission level can be very accurate, but its outcome can only be an indication of the probability that EMC will be achieved.

The amount of emission of electromagnetic energy can be expressed in an emission level (see 2.2 for its definition) if the requirements for the determination of a level, as discussed in A.4, are fulfilled.

In that case the type of disturbance has to be given as well, which means that it has to be indicated which parameter of the emitted electromagnetic energy is considered. Examples of parameters are: magnetic field strength, electric field strength, common-mode current, V-terminal voltage [1]. The parameters thus represent a certain electromagnetic phenomenon (that is a disturbance, see A.4) in which a part of the emitted electromagnetic energy manifests itself. "Part of" is written here on purpose as, in general, electromagnetic energy emanates from a source via conduction and radiation at the same time.

The discussion of immunity measurements follows the same line as in the case of emission measurements. The only important difference is that the defined measuring equipment (device plus instrument) is replaced by a defined disturbance source (generator plus coupling network). The task of this source is to replace all kinds of possible emitters (with often unknown impedance properties) by a reproducible, defined emitter.

Figure A.3 gives an overview of various aspects of emission and immunity measurements. The subdivision in standardized and *in situ* tests will be discussed in clause B.1. Note that the lowest arrows in each column in figure A.3 point from "(test) limit" towards "(test) level" to indicate that the maximum permissible and minimum required levels, i.e. the limits (see 2.2) are quantities which have been agreed upon.

An immunity level is only known after a level causing degradation has been reached, that is after a "lack of immunity", hence susceptibility, has been observed. The immunity level is often unknown in cases where exceeding that level results in a (great) risk of damaging the device. If this risk is present, normally a "go – no go" test is carried out up to an electromagnetic disturbance level which is equal to (or an agreed amount higher than) the minimum required immunity level, i.e. the immunity limit (see also 2.2).

A.6 Compatibility level and margin

From the preceding sections 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 clause 3, 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).

The compatibility level and its margin, defined in 2.2 and 2.3, and already discussed in 3.2.2, might be determined along the following (idealized) lines.

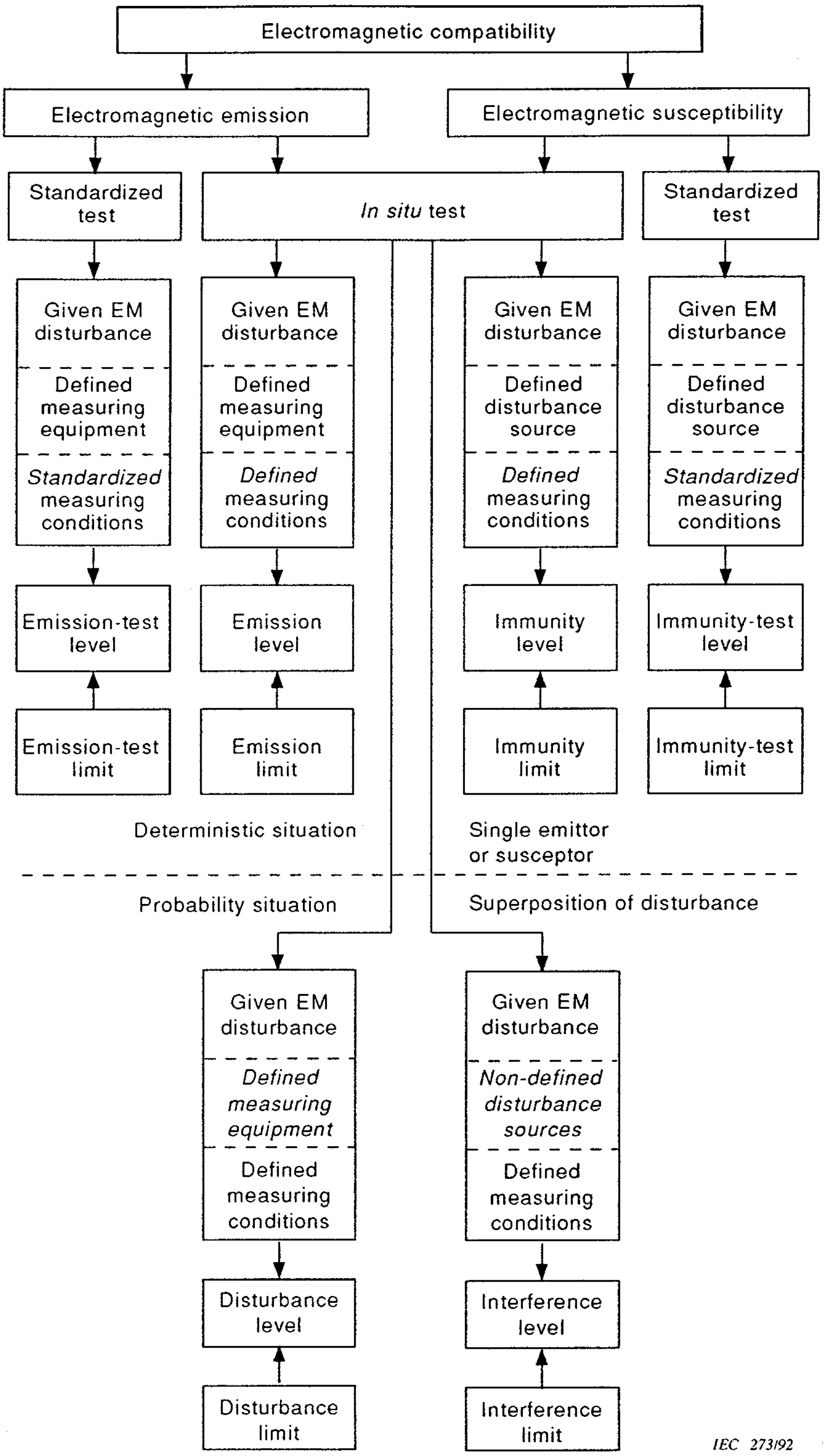

Figure A.3 – Overview of various EMC terms and measuring conditions

If one considers a certain type of electromagnetic disturbance, at a certain value of the independent variable (see 3.3) 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 A.4 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).

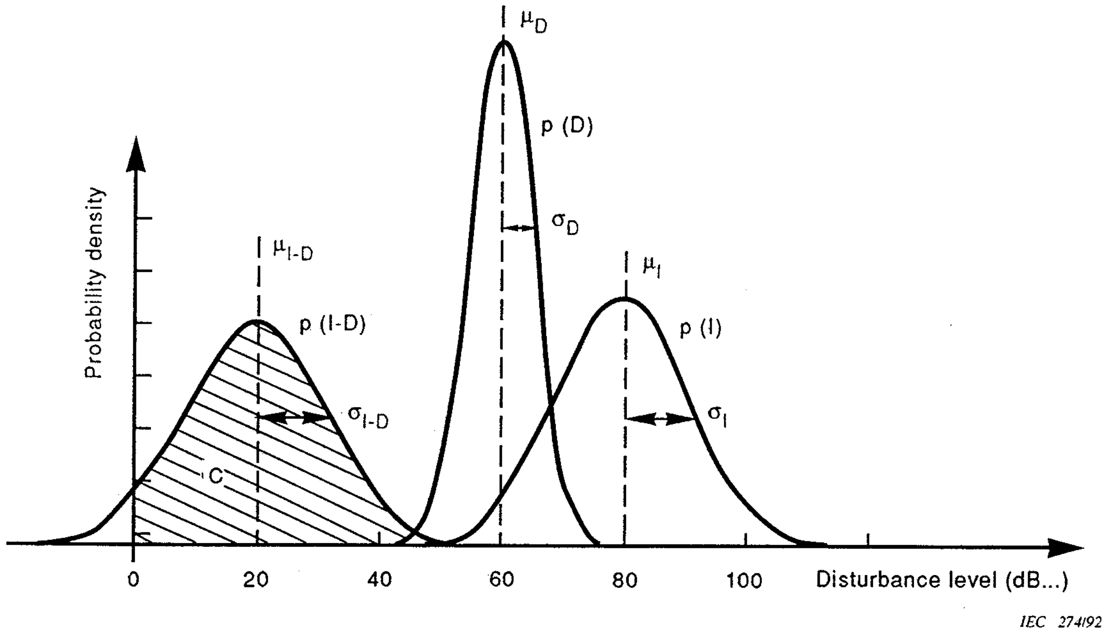

Figure A.4 – Example of probability densities p(D), p(I) and the resulting p(I-D). The area C under the curve p(I-D) for values (I-D)>0 gives the probability of having EMC at the value of the independent variable under consideration

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 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 3.2.2 and 3.3. 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" has to be formulated by the IEC committee dealing with that compatibility level.

Annex B

Standardized and *in situ* tests

For the verification of EMC specifications it is recommended that emission and immunity measurements be carried out in standardized situations, so that the specifications can be verified world wide. However, these measurements can also be of interest at the location where a device, equipment or system is in use. For example, in the case of large systems, which can only be measured *in situ*, or to see how the results of a standardized test work out in the installation.

The standardized test

Standardized tests have three fundamental properties to allow levels to be measured reproducibly all over the world:

1. Only one type of electromagnetic disturbance is considered at a time.
2. In the case of emission: The sensitive device and indicator used to determine the type of disturbance are well defined. In the case of immunity: The source producing the electromagnetic disturbance and the coupling network are well defined.
3. The measurement conditions are well defined and standardized.

The details of these properties have already been discussed in A.4 and A.5.

In the standardized test the electromagnetic environment is always controlled such that the emission level and the immunity level are measurable. In the installation this need not always be the case, as the electromagnetic environment in that situation is not always controllable.

The in situ test

The first two fundamental properties mentioned above can be realized at the location where the device, equipment or system is in use. The third property can be realized only to a limited extent. In particular not all the loading conditions mentioned in clause A.5 can be standardized. To distinguish test results obtained in the standardized test from those obtained in an installation it is preferable to speak about emission/immunity-test level/limit and emission/immunity level/limit, respectively; see figure A.3.

Example:

If the disturbing voltage between reference-earth and line (or neutral), the so-called V terminal voltage [1], has been measured by using a V-network [1] in the standardized emission test, and in the *in situ* test that voltage is measured between a safety earth and line (or neutral), the load impedance for the disturbance source is unknown a priori. If this impedance is measured, one will normally find a time-dependent quantity, because this impedance depends on the loading conditions of the mains network. Hence, the level need not be constant at a given location, when considered over a longer period of time. Consequently, the level cannot now be measured reproducibly all over the world.

In the case of emission measurements other disturbance sources may already emit such a high level of the type of disturbance to be measured that the contribution of the device (equipment or system) under test is drowned completely or, at least, the measuring results are affected by the ambient noise. In such a case it is no longer possible to state that the emission level has been measured, and only the disturbance level (see clause A.4) can be measured.

In the case of immunity measurements other electromagnetic disturbances might be incident on the particular susceptor at the same time, and the immunity level for one type of disturbance need not be independent of the presence of another type.

Example:

The immunity of a digital system to transients on the mains can be reduced appreciably when the system is subjected to a strong field from a broadcasting transmitter. This reduction is caused by the detection of the RF-signal by the nonlinear semiconductor devices used in that system. In such cases it is no longer possible to state that the immunity level/limit has been determined, but only a level at which interference resulted. The latter level might be called the interference level.

Note that the disturbance and interference levels are needed because of the superposition of various electromagnetic disturbances. In the case of emission the electromagnetic disturbances of a *given* type (emitted by various sources) add up and determine the ultimate disturbance level. In the case of the "immunity/interference column" *various* types of electromagnetic disturbances (emitted by various sources) add up and determine the ultimate interference level of a particular susceptor.

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