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TECHNICAL REPORT

BASIC EMC PUBLICATION

Electromagnetic compatibility (EMC) –
Part 1-1: General – Application and interpretation of fundamental definitions and terms

IEC TR 61000-1-1:2023-02(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 1-1: General – Application and interpretation of fundamental definitions and terms

FOREWORD

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IEC TR 61000-1-1 has been prepared by IEC technical committee 77: Electromagnetic compatibility. It is a Technical Report.

It forms Part 1-1 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This second edition cancels and replaces the first edition published in 1992. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the general description of the electromagnetic environment has been updated in accordance with IEC TR 61000-2-5;
b) the description of source, of potentially susceptible equipment/systems and of coupling mechanism has been updated,

c) elements from IEC TR 61000-2-3, that is intended to be withdrawn, as well as from IEC TR 61000-2-5, have been incorporated into this document.

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

Draft	Report on voting
77/586/DTR	77/587/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

IEC 61000 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 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts, published either as international standards or as technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 1-1: General – Application and interpretation of fundamental definitions and terms

1 Scope

This part of IEC 61000, which is a Technical Report, aims 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 equipment and 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 other locations, for example at premises where a device, equipment or system is manufactured or at the location where a device, equipment or system is installed (in situ tests or measurements).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Part 161: Electromagnetic compatibility* (available at www.electropedia.org)

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-161 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
(electromagnetic) compatibility level
specified electromagnetic disturbance level used as a reference level for co-ordination in the setting of emission and immunity limits

Note 1 to entry: 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.

Note 2 to entry: The compatibility level may be phenomenon, time or location dependent.

[SOURCE: IEC 60050-161:1990, 161-03-10]

3.1.2
(electromagnetic) compatibility margin
ratio of the immunity limit to the emission limit

Note 1 to entry: The compatibility margin is the product of the emission margin and the immunity margin

Note 2 to entry: If the levels are expressed in dB(...), in the above margin definitions "difference" is used instead of "ratio" and "sum" instead of "product".

[SOURCE: IEC 60050-161:1990, 161-03-17, modified – note 2 has been added.]

3.1.3
electromagnetic environment
totality of electromagnetic phenomena existing at a given location

Note 1 to entry: In general, this totality is time dependent and its description can need a statistical approach.

[SOURCE: IEC 60050-161:2018, 161-01-01]

3.1.4
electromagnetic disturbance
electromagnetic phenomenon that can degrade the performance of a device, equipment or system, or adversely affect living or inert matter

Note 1 to entry: An electromagnetic disturbance may be an electromagnetic noise, an unwanted signal or a change in the propagation medium itself

[SOURCE: IEC 60050-161:1990, 161-01-05]

3.1.5
electromagnetic interference
EMI
degradation in the performance of equipment or transmission channel or a system caused by an electromagnetic disturbance

Note 1 to entry: Disturbance and interference are cause and effect, respectively.

Note 2 to entry: The English words "interference" and "disturbance" are often used indiscriminately.

[SOURCE: IEC 60050-161:2018, 161-01-06, modified – Note 1 and Note 2 have been revised.]

3.1.6
electromagnetic compatibility
EMC
ability of a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[SOURCE: IEC 60050-161:2018, 161-01-07, modified – the terms "device" and "equipment" have been added to the definition.]

3.1.7
electromagnetic emission
phenomenon by which electromagnetic energy emanates from a source

[SOURCE: IEC 60050-161:2019, 161-01-08]

3.1.8
emission level (of a disturbing source)
level of a given electromagnetic disturbance emitted from a particular device, equipment or system, measured in a specified way

[SOURCE: IEC 60050-161:1990, 161-03-11, modified – "measured in a specified way" has been added.]

3.1.9
emission limit (from a disturbing source)
specified maximum emission level of a source of electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-03-12]

3.1.10
emission margin
ratio of the electromagnetic compatibility level to the emission limit

Note 1 to entry: If the levels are expressed in dB(...), in the above margin definitions "difference" is used instead of "ratio" and "sum" instead of "product".

[SOURCE: IEC 60050-161:1990, 161-03-13, modified – the note has been added.]

3.1.11
degradation (of performance)
undesired deviation in the operational performance of any device, equipment or system from its intended performance

Note 1 to entry: The term "degradation" can apply to temporary or permanent failure

[SOURCE: IEC 60050-121:1990, 161-01-19]

3.1.12
disturbance level
level of an electromagnetic disturbance existing at a given location, which results from all contributing disturbance sources

[SOURCE: IEC 60050-161:1990, 161-03-29]

3.1.13
immunity (to a disturbance)
ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-01-20]

3.1.14
immunity level
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

[SOURCE: IEC 60050-161:1990, 161-03-14]

3.1.15
immunity limit
minimum permissible immunity level

Note 1 to entry: In some product/product family standards the term test level is used to express what is meant by immunity limit.

3.1.16
immunity margin
ratio of the immunity limit to the electromagnetic compatibility level

Note 1 to entry: If the levels are expressed in dB(...), in the above margin definitions "difference" is used instead of "ratio" and "sum" instead of "product".

[SOURCE: IEC 60050-161:1990, 161-03-16, modified – the note has been added.]

3.1.17
level (of a time varying quantity)
magnitude 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 1 to entry: The level of a quantity can be expressed in logarithmic units, for example decibels with respect to a reference value.

[SOURCE: IEC 60050-161:1990, 161-03-01]

3.1.18
(electromagnetic) susceptibility
inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

Note 1 to entry: Susceptibility is a lack of immunity.

[SOURCE: IEC 60050-161:1990, 161-01-21]

3.2 Abbreviated terms

AC	alternating current
DC	direct current
EM	electromagnetic
EMC	electromagnetic compatibility
EMI	electromagnetic interference
RF	radio frequency

4 The electromagnetic environment

4.1 General

There are various approaches that can be used for describing the electromagnetic environment at a considered location. Classification in terms of typical environmental locations such as industrial, residential and commercial can have some meaning in that each of these tends to imply some general characteristics of the electromagnetic environment on which compatibility levels can be based. However, it is recognized that equipment not normally associated with a particular environmental location class can indeed affect the electromagnetic environment at any specific location.

For the above reason, the approach taken in this document is to indicate the electromagnetic levels expected from particular sources or classes of sources. The level expected at a particular location will be determined with reference to the sources existing at that location. IEC TR 61000-2-5 provides a description of the electromagnetic environment with anticipated disturbance levels for typical location classes.

At the same time, it is recognized that one cannot always identify all sources that can affect a particular environment. Such is the case, for example, with conducted disturbances in a power system generated at large distances, for example large distant nonlinear industrial loads or unpredictable exceptionally severe lightning strokes. It is meaningful to make a distinction between public supply and industrial or private networks.

The quality of the provided power supply at the point of common connection due to remote users will depend upon the capacity of the network and the loads connected to it that an individual consumer knows little about. Voltage fluctuations can be caused by load switching as well as by system faults and lightning strokes. Within a consumer's system, residential or industrial, the low frequency effects of local loads can be predicted. In general, one would expect the remote sources to limit the quality of service delivered to a particular consumer location, and that any given system needs to perform properly in the absence of local sources. This is assuming that the quality of service is otherwise satisfactory. Local sources can be expected to have more significant effects in possible system and device degradation.

4.2 Coupling between emitting and susceptible devices

The major reason for considering electromagnetic compatibility is the existence of devices (equipment, systems) which show susceptibility to electromagnetic emission from other devices.

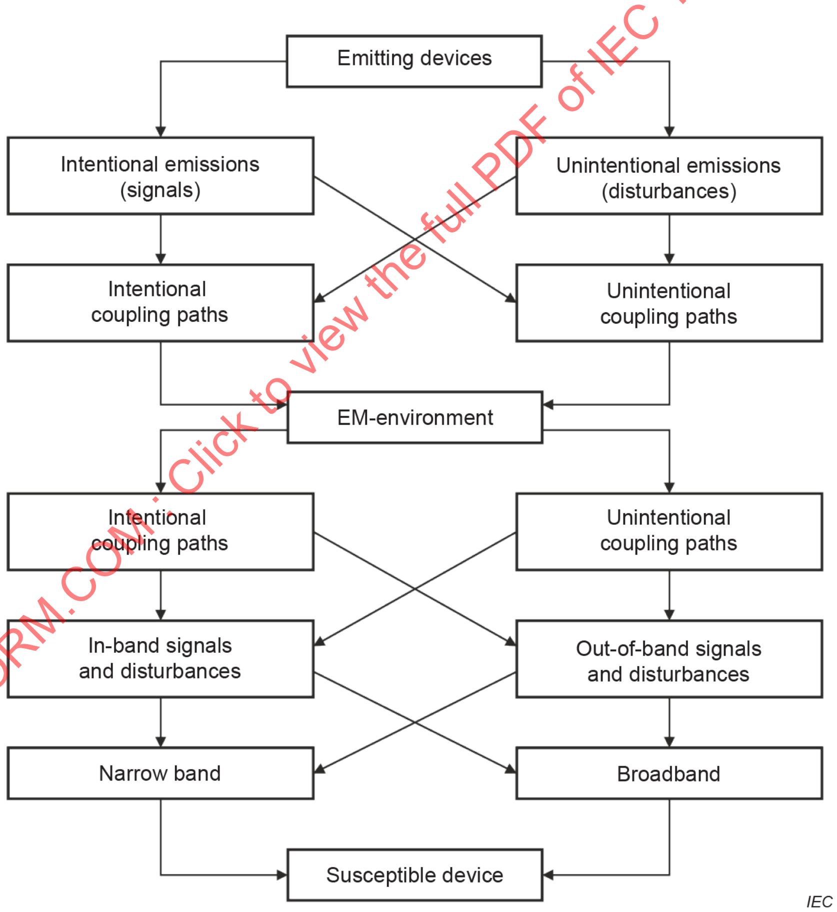


Figure 1 – Coupling paths between emitting and susceptible devices

Emitting devices can have intentional emissions, such as a radio-frequency broadcasting signal, or unintentional emissions. Through various coupling paths such emissions can reach the site where a susceptible device is located as shown in Figure 1, thereby establishing the electromagnetic environment for that device. The subdivisions shown in Figure 1 are important for a description of the electromagnetic environment. Moreover, the technical possibilities available to prevent or solve an interference problem are related to these subdivisions, as are also the relevant EMC specifications.

The susceptible device can be exposed to the electromagnetic environment via intentional coupling paths, such as the aerial of a radio receiver, or via unintentional coupling paths such as the recording head of a video tape recorder, a signal cable or a mains cable. Both types of coupling paths, intentional and unintentional, can carry disturbances having frequency components in the frequency band designated for the desired signal of the susceptible device, and disturbances having components outside that band.

The disturbances received can be considered narrow band or broadband. For example, the disturbance from a switched-mode power supply operating at 40 kHz and its harmonics is narrow band when the bandwidth of the effected radio service is far broader than the bandwidth of the disturbances.

5 Application of EMC terms and definitions

5.1 General

The definitions given in Clause 3 are basic conceptual definitions. When they are applied to assign specific values to the levels in a particular case, several considerations are necessary. A number of these are given in Clause 5, together with examples which will elucidate them. For an interpretation of the various terms used, see Annex A and Annex B.

The basic devices or systems can be divided into two groups:

1) emitters – devices, equipment or systems which emit potentially disturbing voltages, currents or fields, and
2) susceptible devices – devices, equipment or systems whose operation might be degraded by those emissions.

Some devices can belong simultaneously to both groups.

5.2 Relation between various types of levels

5.2.1 Emissions and immunity level (and limit)

A possible combination of an emission level 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 susceptible device, is illustrated in Figure 2.

In Figure 2, the emission level is always lower than its maximum permissible level (the emission limit), and the immunity level is always higher than its minimum required level (the immunity limit). In the illustrated scenario, the emitter and the susceptible device comply with their specified limit. In addition, the immunity limit has been chosen to be higher than the emission limit, and it has been assumed that the levels and limits are continuous functions of the independent variable. These levels and limits can also be discrete functions of some independent variable, see 5.2.3.1.

Further to the above, the following observations are noted:

a) By drawing the emission and immunity levels (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.
b) Drawing the emission and immunity levels 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 2 indicates an electromagnetically compatible situation.

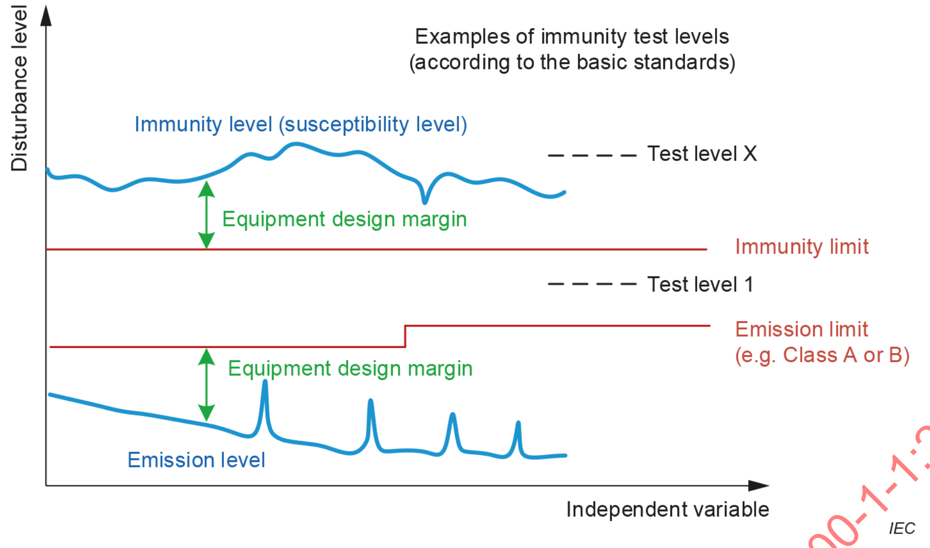


Figure 2 – Limits and levels for a single emitter and susceptible device as a function of some independent variable (e.g., frequency)

As shown in Figure 2, 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 neither been defined in IEC 60050-161 nor in this document, as equipment design issues are the prerogative of the manufacturer. Emission limits are often determined based on radio parameter considerations since radio coverage is closely related to the noise that the radio receivers are able to cope with.

5.2.2 Compatibility level

The concept of compatibility level is illustrated in Figure 3. The solid blue lines indicate a possible emission and immunity level for a single emitter and susceptible device. It is assumed that only one particular disturbance is considered in Figure 3.

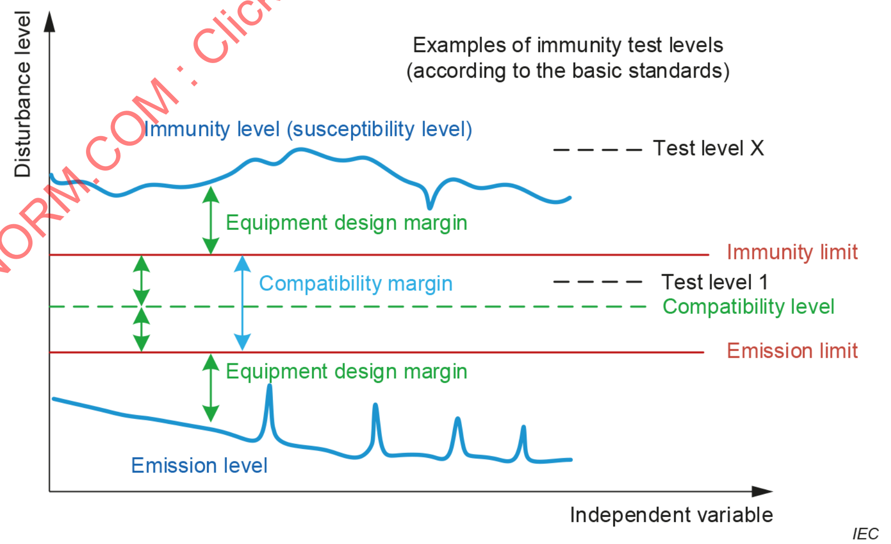


Figure 3 – Emission/immunity limits and compatibility levels, with an example of emission/immunity levels for a single emitter and susceptible device as a function of some independent variable (e.g., frequency)

Further to the above, the following observations are noted:

a) 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 5.2.3.2 below), the compatibility level can be expressed in the unit corresponding to either the emission level or the immunity level.

b) If the electromagnetic environment is controllable, a compatibility level can 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.

c) 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.

d) 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.

e) The determination of limits from the compatibility level is governed by probability considerations, discussed in 5.3. In general, these limits are not at equal distances from the compatibility level, see also 5.3. In Clause A.7, the compatibility level is determined for an idealised situation, where the probability density functions are assumed to be known.

5.2.3 Examples to illustrate the concepts of using levels and limits

5.2.3.1 Emission and immunity levels and limits

Let one 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, let one 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 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 4).

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, is likely to 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 is a high probability that the immunity level U_i of each appliance connected to the network fulfils the relation $U_i > U_d$.

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

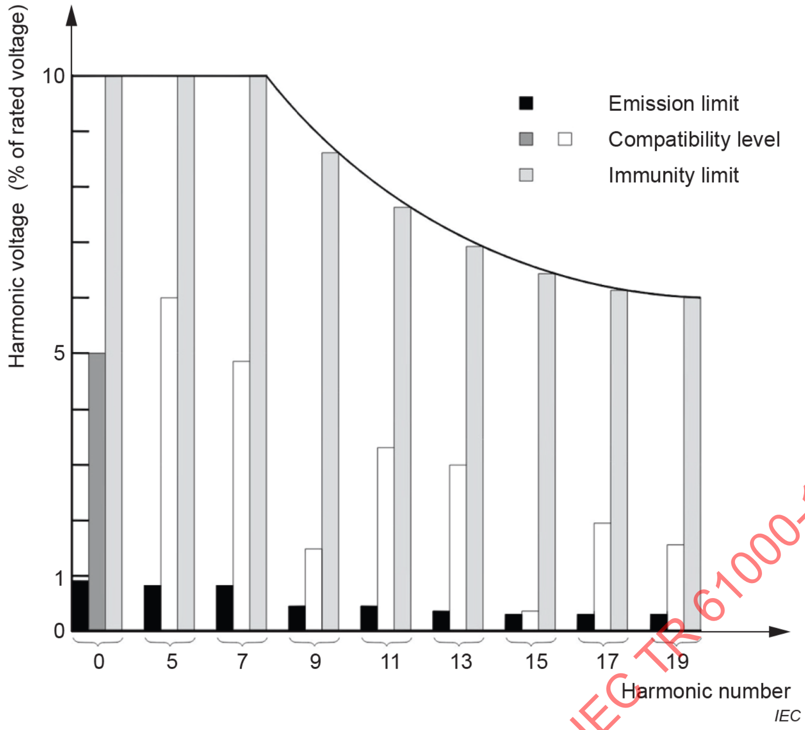


Figure 4 – Compatibility levels U_c for the odd harmonics in a public low-voltage network and examples of associated emission and immunity limits

Also given in Figure 4 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.

The emission limit is also given to illustrate a problem. In IEC 61000-3-2:2018, Table 1, the emission limit is given as the maximum permissible harmonic current in amperes. However, the presentation in Figure 4 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 IEC 61000-3-2. In line with the above reasoning, the maximum harmonic voltage ratios given in IEC 61000-3-2:2018 and IEC 61000-3-2:2018/AMD1:2020, Annex A, are plotted in Figure 4. Note that in IEC 61000-2-2, a distinction is made between the odd harmonics that are a multiple of 3 and those that 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 4, 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 5.3.

To fulfil the second requirement a sufficiently strict immunity limit is needed, of which an example is given in Figure 4. A distance between this limit and U_c, i.e., an immunity margin, is needed because:

a) 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; and

b) 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 document.)

It is possible to specify a continuous immunity limit as illustrated in Figure 4. 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 can be a need to convert the percentages in which the immunity limit is given in Figure 4 to absolute values. An example for the derivation of disturbance degrees and immunity limits for the phenomenon of high frequency radiated disturbances is given in Annex C.

5.2.3.2 Compatibility level

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

Let one consider the immunity to RF fields of equipment having dimensions that are 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. Hence, the interrelated radiated and conducted phenomena will be taken into consideration when attempting to achieve EMC.

With regard to 5.2.1, 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 2 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, for example, a test generator.

With regard to Figure 3 and the foregoing considerations, the compatibility level can 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 can also be determined by the susceptibility properties of the susceptible device 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.

5.3 Probability aspects and margins

5.3.1 Compatibility levels and uncertainties

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 5 represents an electromagnetically compatible situation for the single emitter and susceptible device under consideration.

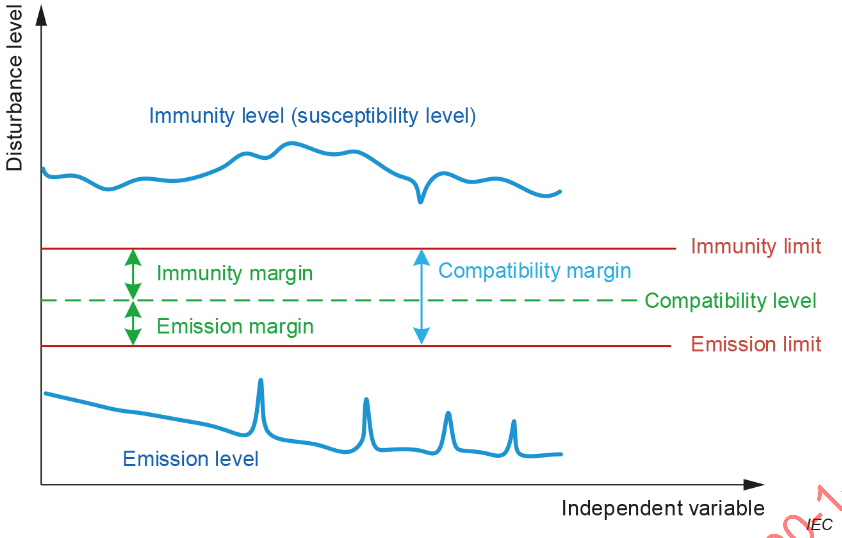


Figure 5 – Limits, compatibility levels and margins, as a function of any independent variable (e.g., frequency)

Indeed, Figure 5 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 5 does not guarantee that EMC will exist in the actual situation, as there are uncertainties, already briefly mentioned in 5.2.2.

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 specified. In Figure 5, the margins, defined in 5.3, are shown as solid lines. The difference between the emission (and immunity) level and the emission (and immunity) limit is known as the equipment design margin, and this is determined by the manufacturer as already discussed in 5.2.1. Four important uncertainties will be discussed in 5.3.2 to 5.3.4.

5.3.2 Standardized test

5.3.2.1 Uncertainty contributions in standardized tests

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

1) the relevance of the test method, including measurement instrumentation uncertainty; and
2) the normal spread of component characteristics in the case of mass-produced equipment.

For more details on the standardized test, refer to Annex B. The above-mentioned uncertainties are discussed in detail below.

5.3.2.2 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 susceptible device. 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 susceptible devices 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.

5.3.2.3 Normal spread of component characteristics

Not all devices, equipment or systems, especially those that are mass 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 6. Hence, there is an uncertainty as to whether a randomly chosen equipment from that mass-production will comply with the limit. This uncertainty is considered in detail in CISPR TR 16-4-3, the part on the so-called "“80 %/ 80 % compliance rule". This 80/80 rule requires that equipment in series production be tested to ensure an 80 % confidence that at least 80 % of the products comply with the limits. The distributions are also determined by the reproducibility of the test method.

It is noted that curves similar to those given in Figure 6 will be found for each value of the independent variable, for example, frequency, in the specified EMC test. Hence, Figure 6 can only apply to the test data for one single value of the independent variable.

From Figure 6, 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 6 also shows that the manufacturer had chosen a certain equipment design margin. In some cases, see for example CISPR TR 16-4-3, the 80 %/80 % compliance rule creates the need for a minimum equipment design margin, where this margin depends on the EMC test sample size.

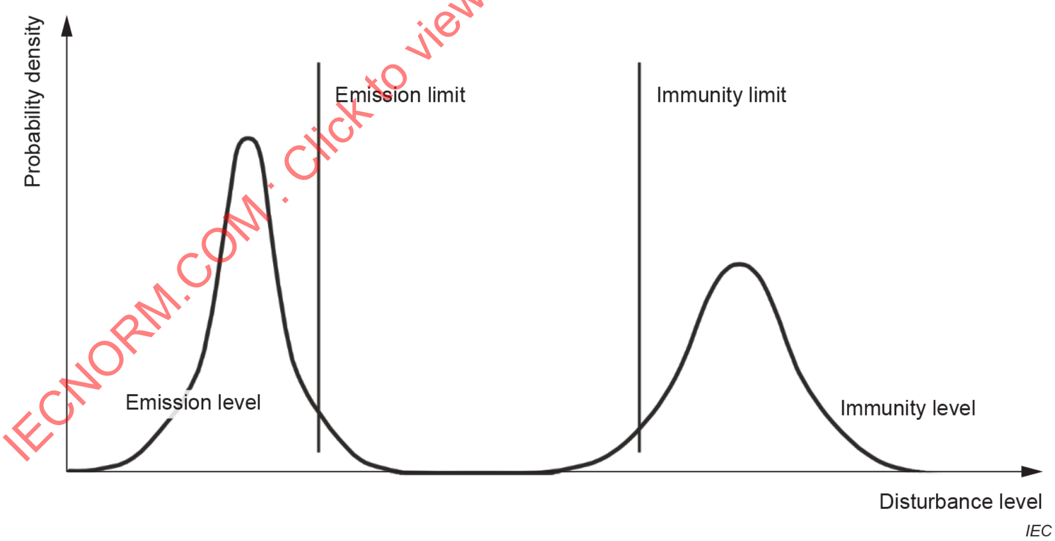


Figure 6 – Example of the probability densities for an emission level and an immunity level, at one single value of the independent variable

5.3.3 In situ test – Superposition

5.3.3.1 General

In addition to the two uncertainties mentioned in 5.3.2, 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 is 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 can differ from those in the standardized test.

5.3.3.2 Superposition effects, multidimensional criteria

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

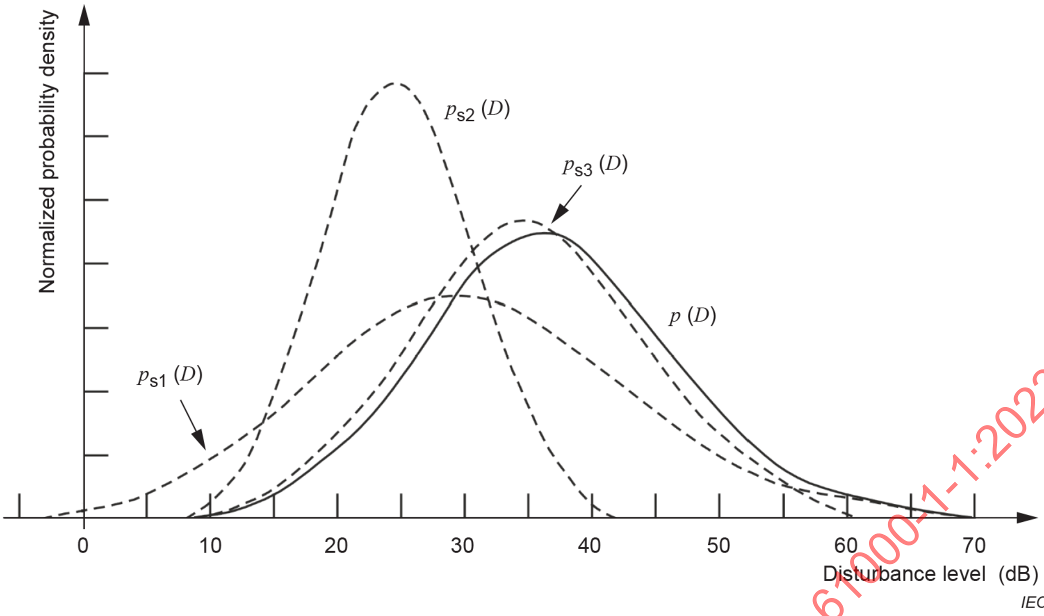
a) the superposition of disturbances of the same type, where each disturbance contribution depends on the loading conditions of its emitter, on the electromagnetic propagation properties between that emitter and the susceptible device, and on time; and
b) contributions of other types of disturbances, having components in the susceptible device 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.

5.3.3.3 Example for the superposition of disturbances

An example of the superposition of disturbances is given in Figure 7. In this example, it is assumed that there are three types of emitters emitting the same type of disturbance. As with Figure 6, 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 document, other types of distributions are also possible.



The ultimate disturbance level probability density, $p(D)$, originates from the probability densities $p_s(D)$ of various types of sources.

Figure 7 – Example of superposition of disturbances

The ultimate disturbance level is of importance to all possible susceptible devices at a particular location (in a particular system), where each type of susceptible device will have its specific immunity properties (see Figure 8) 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 susceptible device simultaneously, and this is another type of superposition. The immunity level for one type of disturbance can be negatively influenced by the presence of another type of disturbance (see Annex B). Consequently, there is an additional need for additional margins.

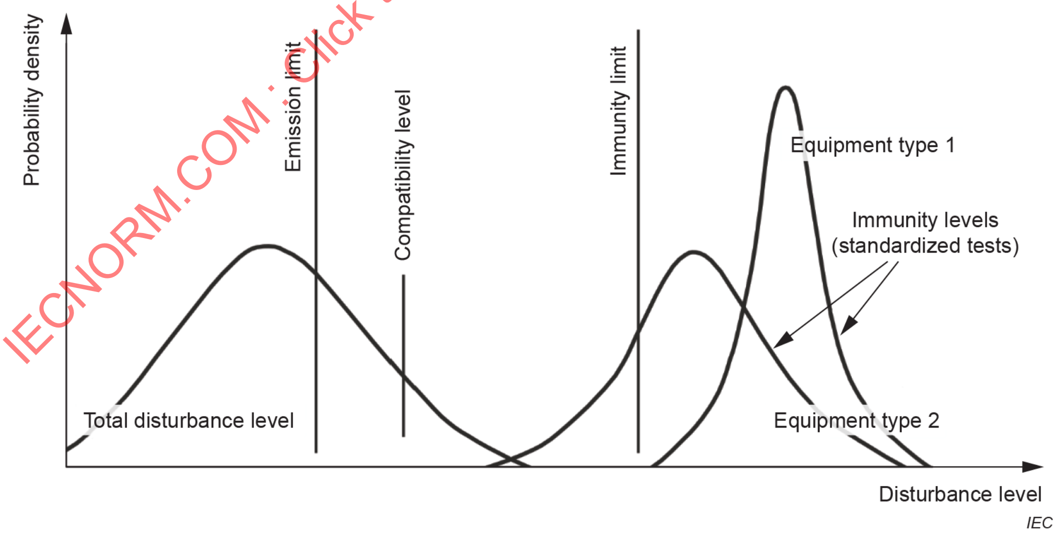


Figure 8 – Example of probability densities for an ultimate disturbance level (the sum of disturbance levels produced by various emitters) and the immunity levels of two types of susceptible device

5.3.4 Lack of data

Generally, there is no time, or it is impossible, to measure the disturbance levels at all possible locations where a susceptible device may be installed, and therefore the disturbance probability density given in Figure 8 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 susceptible device 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 specified.

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.

6 Models and their limitations

6.1 General

When electrical and electronic devices and their electromagnetic emissions and coupling paths (which impact immunity) are examined in detail, they can be found to be extremely complex and for this reason, a standardized test is viewed as the preferred way to evaluate the emissions and immunity of electronic equipment. If there is a need to understand the emissions from and the coupling into electronic equipment, it can be useful to use modelling to determine the likely cause of problems and how the equipment could be modified in order to satisfy testing requirements. Also, modelling can be useful in the design of electronics to minimize interference issues. However, in spite of the advancements in modern modelling tools, there is always a need to simplify the modelling as every product can have some minor variations in wiring that can affect detailed modelling results. Disturbance sources emit by mechanisms of conduction, induction and radiation. Coupling paths from the outside of an equipment to the inside can occur through conduction, induction or radiation, and most usually by combinations of these phenomena.

6.2 Source models

6.2.1 Conducted emissions

For conducted emissions, the source can often be considered as a two-port or three-terminal device. Figure 9 shows noise sources in differential mode (V_{DM}) and in common mode (V_{CM}). Connection points 1 and 2 can be identified as, for example, the neutral and the phase of a mains connection, or as the connection points of a desired signal of a control line. Connection point 0 represents the reference of the source formed, for example, by the protective earth, the steel reinforcement in a building, or a metal chassis. In many cases it can be necessary to consider the source as an N-port network, as in the case where a multi-wire flat cable is involved.

The voltages V_{DM} and V_{CM} are complex voltages having desired as well as disturbance components. However, the desired voltage from the source, whether this is a power line or a signal line, is predominantly represented in the V_{DM} component. The disturbance voltage components of V_{DM} and V_{CM} can be of equal importance.

It can therefore be recognized that measurements of emission from sources are of a limited nature. For example, to determine compliance with a conducted emission limit, the measurement is made with a specified terminating impedance. No direct measurement of the source impedance is made. Thus, when a given source is placed in a circuit which presents an impedance to it which is different from the measurement impedance, the actual emission will differ from that measured. Such variations need to be anticipated by system EMC engineers when designing compatible systems.

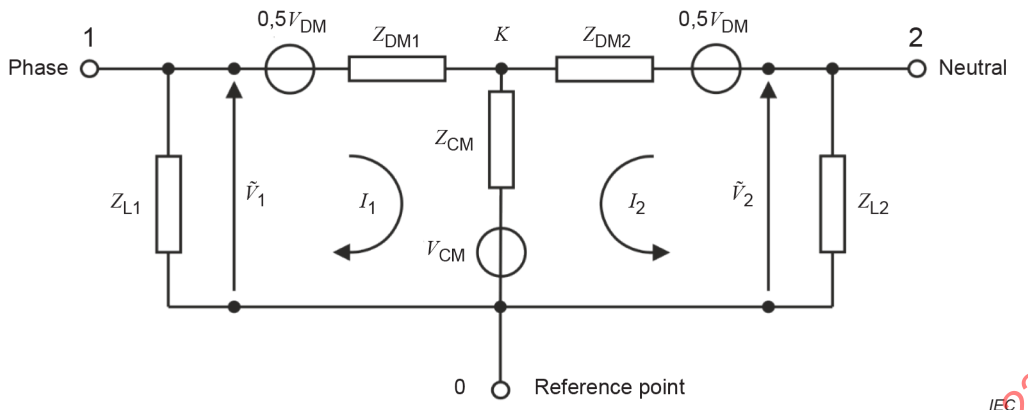


Figure 9 – Source model for conducted emissions (source loaded by Z_{L1} and Z_{L2})

6.2.2 Radiated emissions

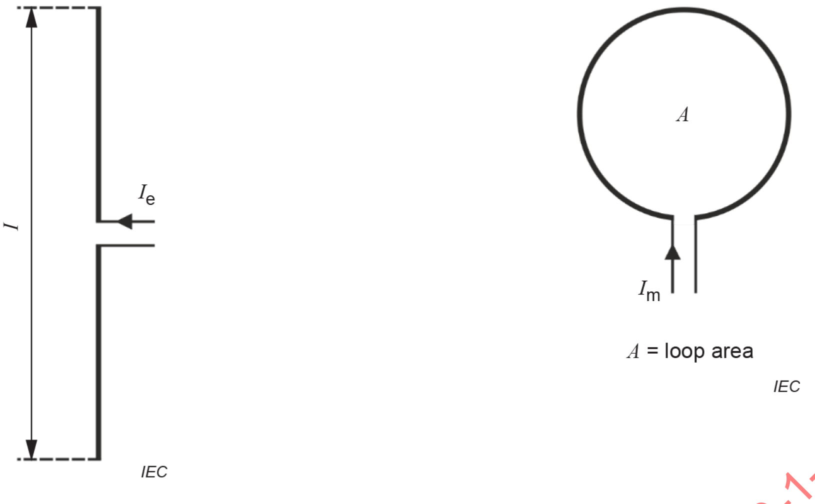
Radiated emission levels are usually stated in terms of electric (E) and magnetic field (H) levels, expressed in dB(μV/m) and dB(μA/m) respectively. Particular sources differ in the relative magnitudes of each of these components and their variations with distance.

In the so-called far-field region of a source the distance between the source and the point of observation of the field is much larger than $\lambda/2\pi$, where λ is the wavelength of the field, and larger than the dimensions of the source. At such distances, and in the absence of nearby reflecting objects, the E and H fields are perpendicular to each other and perpendicular to the direction of propagation of the wave. In addition, there is a fixed relation between the magnitudes of E and H, which makes statements of electric field strength and magnetic field strength equivalent. In the far field and free space $\frac{E}{H} \approx 377\ \Omega$ and the field levels fall off inversely with distance from the source.

In the near-field region of the source, the distance between the source and the point of observation is either much smaller than $\lambda/2\pi$ or smaller than the dimension of the source or both. The relation between the E and H fields now depends on the wavelength of the disturbances, the actual position in the near-field region and the type of source.

A simple model used for radiation is the dipole which can be of electric or magnetic types (see Figure 10). This model exhibits an inverse cubed variation of the field strength of its dominant component (electric field for an electric dipole, magnetic field for a magnetic dipole) at near field distances. For such sources a statement of the "dipole strength" would enable calculation of the field components (both electric and magnetic) at any distance. However, it is more usual to measure the dominant component at a fixed distance, without making reference to the source strength.

In case of radio transmitters, the gain of the antenna in the intended coupling path and the net power P_T transferred to the antenna are usually known. As the antenna gain is always directional with respect to the antenna, the gain normally referred to is that associated with the direction of maximum radiation.



(a) Electric dipole strength = $l \cdot I_e$ **(b) Magnetic dipole strength = $A \cdot I_m$**

Figure 10 – Electric and magnetic dipole elements

6.3 Coupling models

6.3.1 General

The phenomena involved in transferring electromagnetic energy from an external source to a susceptible device in an immunity test, are, in general, very complex. Exact calculation of the energy transferred in particular cases can therefore be difficult. However, in many cases the important coupling can be described in terms of comparatively simple models. These models are divided into three main classes: common impedance coupling, coupling by induction (near-field) and radiative (far-field) coupling.

6.3.2 Common impedance coupling

6.3.2.1 Conductive coupling

Common impedance coupling is also referred to as conductive coupling. It occurs when currents or a portion of the currents associated with a source and susceptible device share a common path. Typically, the common path can be represented by a resistance, an inductance or a capacitance or by a combination of any of these.

Two of many examples that can be cited are the sharing by the source and susceptible device of:

a) a common power mains, and

b) a common ground current return path.

6.3.2.2 Resistive coupling

The resistive part of the common impedance R_c is determined by the conductor material and by the skin effect as a result of which the resistive part becomes frequency dependent. For a straight round conductor of diameter d, one has:

$$\frac{R_c}{R_{dc}} \approx \frac{d}{4\delta} \qquad \text{when } \delta \ll d\text{;and}$$

$$\frac{R_c}{R_{dc}} \approx 1 \qquad \text{if } \delta \gg d$$

where R_{dc} is the DC resistance of the conductor and δ the skin depth given by:

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}}$$

where ω is the angular frequency of the signal, μ the permeability and σ, the conductivity of the conductor material.

6.3.2.3 Reactive coupling

The reactive part of common impedance coupling can be produced by a common inductance. The common inductive reactance X_L can then be written as:

$$X_L = j\omega L_L$$

where L_L is the inductance of the conductor. The value of L_L depends on the shape of the current loop and its surroundings. However, as a rule of thumb, one can say that $L_L = 1\,\mu\frac{H}{m}$ (or $1\frac{nH}{mm}$). In many electromagnetic interference problems $X_L \gg R_c$. For transient events, this is always the case, in spite of the emphasis given to massive earthing conductors.

6.3.3 Coupling by induction

6.3.3.1 Field coupling

6.3.3.1.1 Coupling mechanisms

Coupling by induction occurs when voltages or currents are induced in the circuits of the susceptible device by local electric or magnetic fields or combinations of these emanating from the source. Examples are control circuits located in the vicinity of a large power transformer, arc furnace or welder and closely spaced (and parallel) transmission circuits such as a power line and a telecommunications line.

6.3.3.1.2 Electric field coupling

Electric field or capacitive coupling occurs when electric fields from one circuit impinge on another. For the low-frequency approximation it is appropriate to describe this type of coupling with a coupling capacitance. The magnitude of the capacitance depends primarily on the actual situation, i.e., on the shape of the circuits and on the surroundings of the circuits. An example is given in Figure 11, where the coupling capacitance C_{12} per unit length is given between the wires (of diameter d) of two parallel loops at a distance D, using the ground plane as a common return, for three values of the loop height.

Figure 11 clearly shows the influence of the surroundings on C_{12}. It also shows that C_{12} varies rapidly with D but that for $\frac{D}{d} > 10$ the coupling capacitance does not vary much with D. Note that for sufficiently high values of h the formula for the coupling capacitance reduces to:

$$C_{12}(h \to \infty) = \frac{\pi\varepsilon}{\ln\left(\frac{2D}{d}\right)} \qquad \text{[F/m]}$$

which is the formula for the capacitance between the wires in the absence of a ground plane.

The above example applies equally to two cables running parallel to a metallic plane, i.e. a shield or conduit, which forms the reference for the common-mode voltages on the cables.

In cases where the feedback from the receptor circuit to the emitter circuit is negligible and the circuits are small compared with the wavelength under consideration, the disturbance caused by capacitive coupling can be represented in the receptor circuit by a current source. The current source can be approximated by

$$I_{\mathrm{c}} = j\omega C_{12} V$$

where V is the driving voltage at the emitter side of C_{12}.

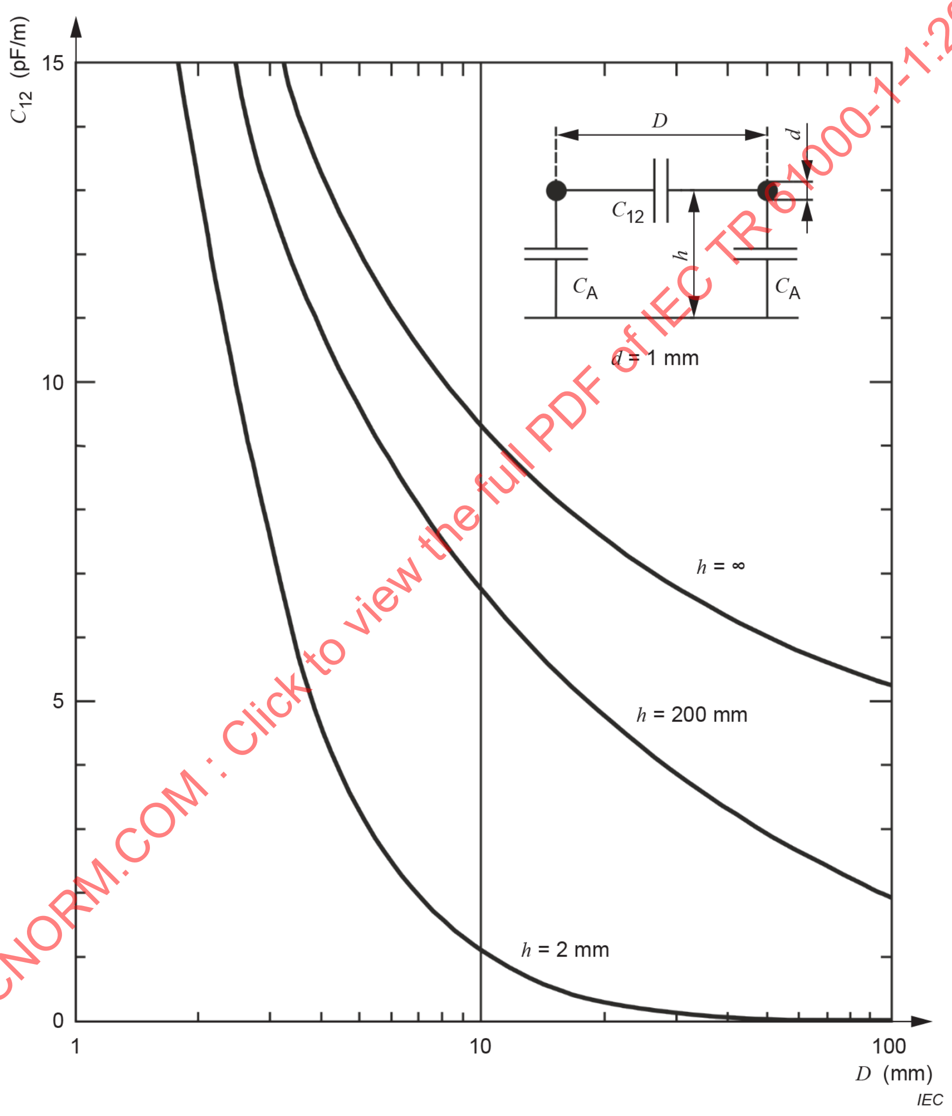


Figure 11 – Capacitance per unit length as a function of conductor separation

6.3.3.1.3 Magnetic field coupling

Magnetic field or inductive coupling occurs when magnetic fields from one circuit impinge on another. An appropriate quantity to describe this type of coupling is the mutual inductance. Its value depends greatly on the actual situation, for example on the shape of the circuits and on the surroundings of the circuits, as in the case of the coupling capacitance.

In cases where the feedback of the receptor circuit to the emitter circuit is negligible and the circuits are small compared with the wavelength under consideration, the disturbance caused by the magnetic coupling can be represented in the receptor circuit by a voltage source. The voltage source can be approximated by:

$$V_1 = j\omega M_{12} I$$

where M_{12} is the mutual inductance between the two circuits involved and I the driving current in the emitter circuit. This can also be written as $j\omega B_1 A_2$ where A_2 is the area of the receptor loop and B_1 the flux density produced by the emitter loop in the receptor loop. In the last relation it is assumed that B_1 is perpendicular to the plane of the receiving loop and uniform over the area A_2.

A very useful model is one that accounts for the magnetic field in the vicinity of a parallel wire transmission line. Its magnitude as a function of parallel wire spacing and the distance from the wires is shown in Figure 12. If the distance is large compared with the separation, the field strength falls off as $1/r^2$. If the distance is small compared with the spacing, the field is calculated as for a single wire (the closest wire).

Magnetic sources such as transformers, relays, etc., will produce field strengths attenuated as the third power of the distance.

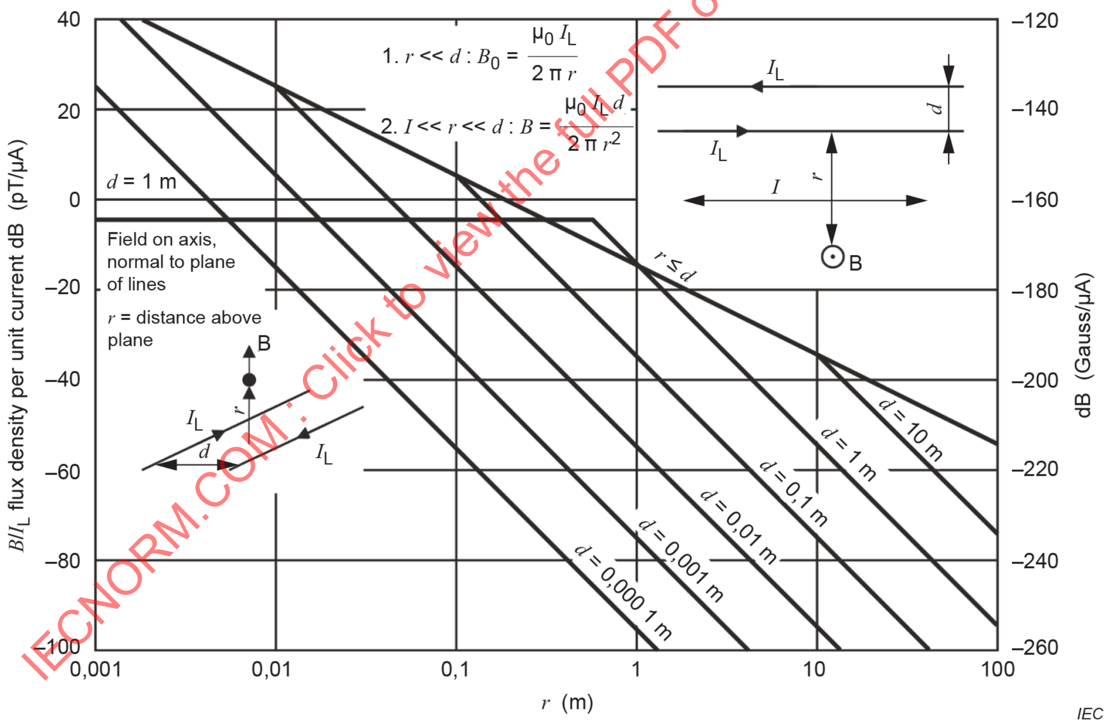


Figure 12 – Flux density from parallel conductors

6.3.3.1.4 Mixed coupling

In many cases the coupling mechanisms discussed in the preceding subclauses 6.3.3.1.2 and 6.3.3.1.3 occur simultaneously. Which of the three mechanisms will dominate depends on the actual situation. Only in a limited number of cases will it be possible to indicate whether capacitive coupling will dominate over magnetic coupling, or vice versa. An example is the case of coupling between two parallel wires. Assuming the receptor circuit to be terminated by its characteristic impedance on both ends, magnetic coupling dominates if the emitter circuit is terminated with an impedance lower than the characteristic impedance and capacitive coupling dominates if that impedance is higher.

6.3.4 Radiative coupling

Radiative coupling can be the primary means of coupling when the source and the susceptible device are relatively far apart, i.e., in the far-field situation. The coupling mechanism by electromagnetic radiation and the voltages induced in the susceptible device circuits can be calculated from either the electric or the magnetic field component of the field as these have a fixed relationship. Generally, there is no feedback from the susceptible device to the source.

An example of radiative coupling is a sensitive receiver or control element affected by the field produced by a relatively distant radar transmitter or high-frequency industrial heating equipment.

6.4 Susceptible device models

Disturbing energy is coupled to a susceptible device in the same way as it is coupled from an emitter, i.e., by either conduction, induction or radiation. The models are simplified so as to provide statements on the levels of disturbing voltage or current on connected power, signal or control lines, and levels of homogeneous electric or magnetic fields, assuming the most disturbing polarization, in which a given device or equipment can be immersed.

Of course, the levels can be dependent on the waveform and frequency of the disturbance, its repetition rate (whether periodic or almost periodic) and the characteristics of internal circuits. Many mechanisms of generation of interference within a device have been discussed in the literature, but it is beyond the scope of this document to review them here.

It is important, however, to note that the preferred parameters used in describing the environment depend upon the characteristics of the equipment under consideration.

Annex A
(informative)

Interpretation of EMC terms and definitions

A.1 General

In Annex A the terms and definitions given in Clause 3 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 Units and decibels

In the EMC sphere, logarithmic expressions for physical quantities are often used. The decibel (dB) was originally defined as a ratio r of two powers P_1 and P_2 dissipated in a resistance R, expressed as a logarithmic unit as follows:

$$r(dB) = 10 \log_{10}\left(\frac{P_1}{P_2}\right) = 10 \log_{10}\left(\frac{V_1^2 / R}{V_2^2 / R}\right) = 20 \log_{10}\left(\frac{V_1}{V_2}\right)$$

where P_1 and P_2 are measured or determined under identical conditions. Hence, r can be expressed in terms of the associated voltages V_1 and V_2 as indicated in the above formula. If V_2 is chosen to be a unit value, for example 1 μV, and V_1 is expressed in terms of that unit, then r gives the magnitude of V_1 expressed in "dB with respect to 1 μV", normally abbreviated to r (dB μV). This latter approach is widely used in the field of EMC. Hence, if Y is a unit value then X dB(Y) is defined as:

$$X(\text{dB}(Y)) = 20 \log_{10}\left(\frac{X}{Y}\right)$$

Certain conventions exist for the choice of Y. Here are some examples:

1) In the case of conducted emissions, the voltage is expressed in dB μV, i.e., decibels above 1 μV; and the current in dB (μA), i.e., in decibels above 1 μA. For example, 120 dB (μV) corresponds to 10^6 μV or to 1 V.

2) In the case of radiated emission, the electric field strength is expressed in dB ($\mu V/m$) and the magnetic field strength in dB ($\mu A/m$). For example, 34 dB ($\mu V/m$) corresponds to 50 $\mu V/m$. In cases where the magnetic field strength, H, at frequencies above 30 MHz is expressed in dB ($\mu V/m$), the unit of the electric field strength E, where dB ($\mu A/m$) would be more appropriate, the magnetic field H expressed in dB ($\mu A/m$) and in dB ($\mu V/m$) satisfies the relation:

$$H(\text{dB}(\mu A / m)) = H(\text{dB}(\mu V / m)) - 51{,}5(\text{dB}(\Omega))$$

where $51{,}5(\text{dB}(\Omega)) = 20 \log_{10} Z_0$ when $Z_0 \approx 377\ \Omega$ and $Z_0 = E / H$

The wave impedance $Z_0 \approx 377\ \Omega$ applies only to the case of a plane electromagnetic wave. However, this is not relevant here as the measurement display is calibrated in such a way that the signal induced by the magnetic field H in the magnetic field antenna, is interpreted as a signal produced by an electric field of strength $E = Z_0 H$.

A.3 Electromagnetic interference, compatibility and environment

A.3.1 General

The ever-increasing number of applications of electrical and electronic equipment is likely to give 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.

A.3.2 Electromagnetic interference (EMI)

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

Electromagnetic interference (EMI) (see 3.1.5): degradation in the performance of equipment or transmission channel or a system caused by an electromagnetic disturbance.

The electromagnetic disturbance (see 3.1.4) mentioned in this definition has been defined as 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 or disturbance: The English words "interference" and "disturbance" are often used indiscriminately. However, it is 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 is called disturbance voltage, and not interference voltage.

b) Elementary form of EMI problem: The definition of EMI refers to "degradation of 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 – a source emitting the electromagnetic disturbance;
   2) a susceptible device – a susceptible device, equipment or system showing degradation of its performance; and
   3) a coupling path – a medium in between the emitter and susceptible device.

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

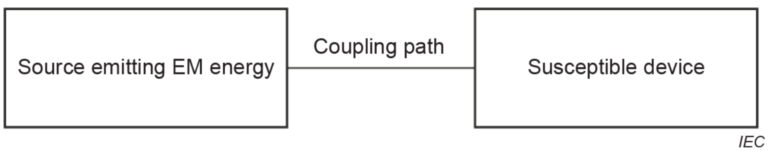


Figure A.1 – The basic form of an EMI problem

c) Degradation*:* Degradation is 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 developing EMC specifications. The kind of departure in the operational performance which is considered to be undesired can be made clear in these specifications.

EXAMPLE: Assume a computing system needs 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 will switch from mains to battery and vice versa. In many cases this departure is fully acceptable.

A.3.3 Electromagnetic compatibility (EMC)

In Clause A.2 it is stated that: "If all devices could exist side by side in harmony, the world would be electromagnetically compatible (EMC)*".* The addition of a device to that environment without causing EMI then means that this device has the property of being electromagnetically compatible. Thus, EMC is defined as the "ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.*"* (see 3.1.6).

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, previously mentioned with respect to EMI, are equally 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.

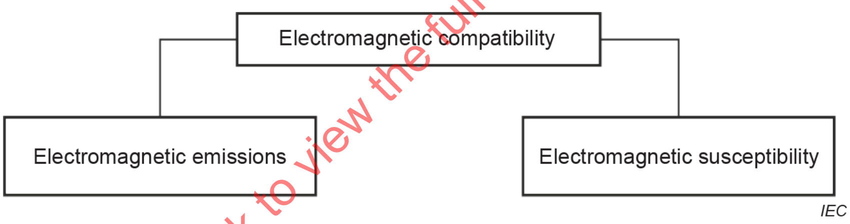


Figure A.2 – Subdivision of EMC in its key aspects

A.3.4 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 susceptible devices 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, as used in EMC applications, is defined as (see 3.1.3) the “"the totality of electromagnetic phenomena existing at a given location".

NOTE In general, this totality is time dependent and a statistical approach can be used to describe it.

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

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.

A.4 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 is given as follows (see 3.1.18): "inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance".

The opposite of susceptibility is immunity. Immunity is defined as (see 3.1.13): “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 is surely negative, for the following reasons.

As pointed out in Clause A.3, 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 60050-161, where the note accompanying the definition of susceptibility states that susceptibility is a "lack of immunity". 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 is noted that an immunity requirement is always specified for a given type of electromagnetic disturbance which is incident in a specified way; see also Clause A.6.

A.5 Level and limit

When developing EMC specifications, specific values have to be assigned to the levels of electromagnetic disturbances in the particular cases. The definition of level reads (see 3.1.17): "magnitude of a quantity evaluated in a specified manner".

The definition of electromagnetic disturbance reads (see 3.1.4): “electromagnetic phenomenon that can 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 description of a disturbance level has to reflect this requirement, so it is described as: 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 or measured in a specified manner or way means:

The measuring device is sufficiently defined and chosen with 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 is sufficiently defined and chosen with 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 are described. A measuring set-up will present certain load impedances to the disturbance source(s) in the equipment under test (EUT). These impedances can be standardized, for example in type tests, or can depend on the conditions at the place of installation, for example in the case of in situ tests (see also Annex B, item a)2)).

The test configuration has to be described in detail. This description needs to 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 can 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 will 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 disturbance limit can be described as follows: 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.6 Emission and immunity

As emission is one of the two key aspects of EMC and EMI, its definition is rather broad and reads (see 3.1.7): "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 will 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 5.2 for its definition) if the requirements for the determination of a level, as discussed in Clause A.5, 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. The parameters thus represent a certain electromagnetic phenomenon (that is, a disturbance, see Clause A.5) 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 Annex B. 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 5.2) 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 5.2).

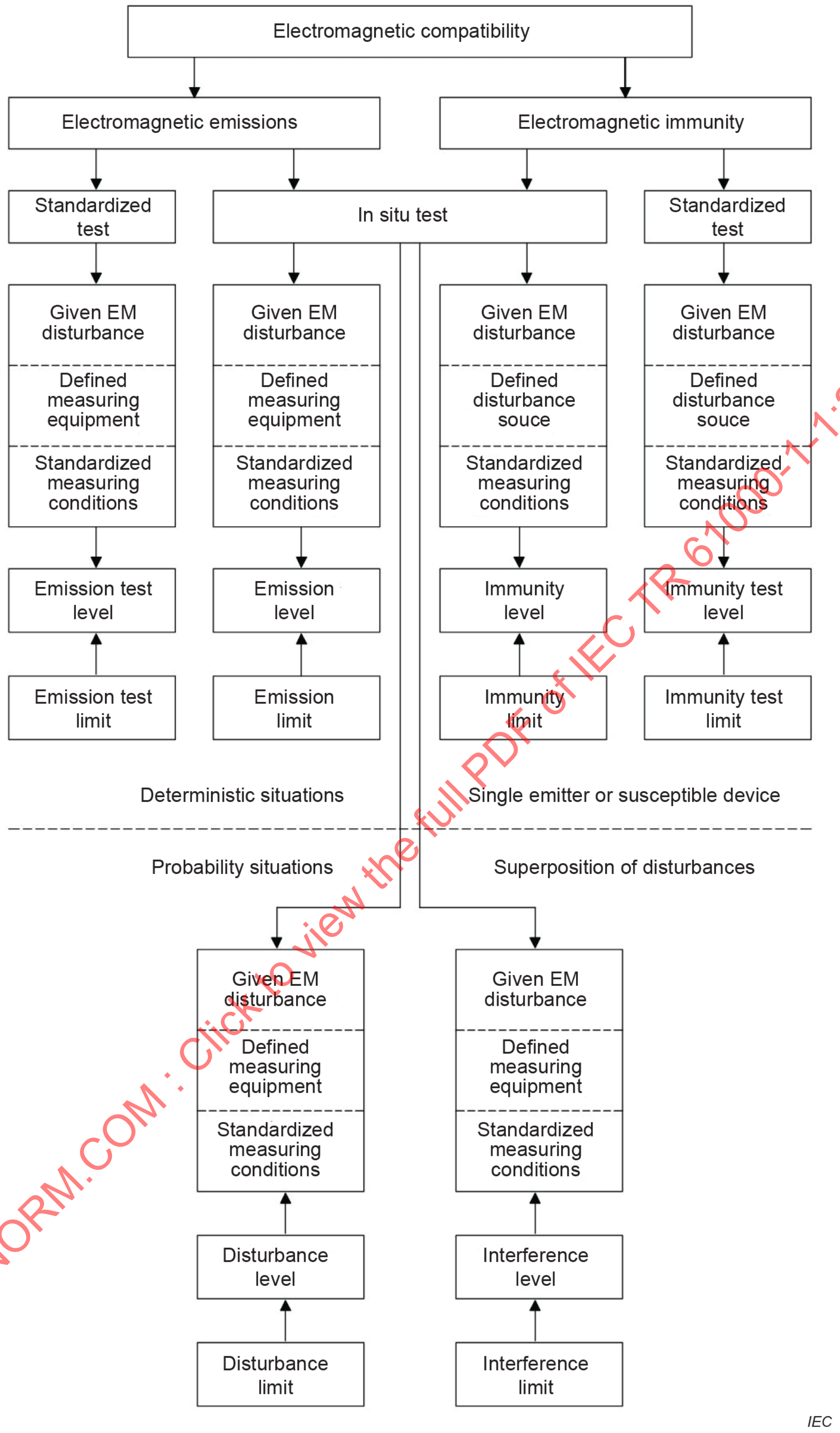


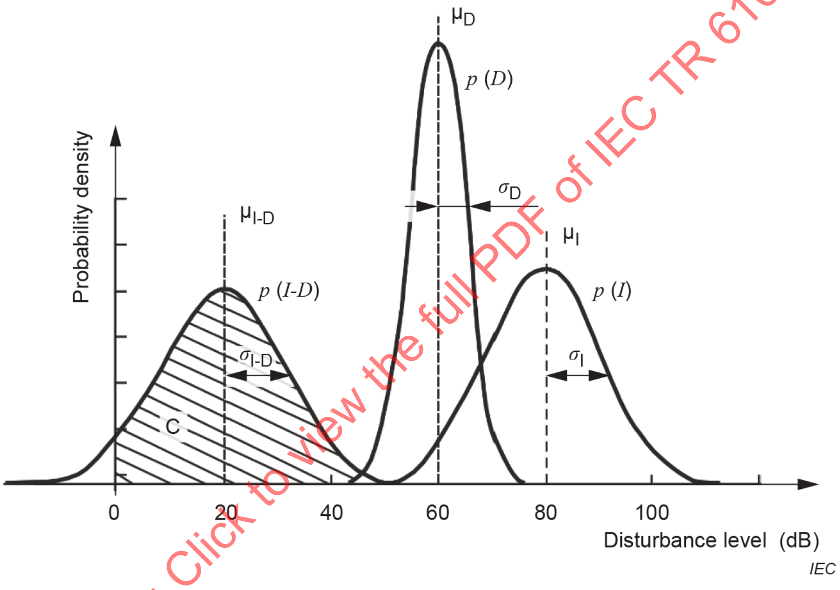
Figure A.3 – Overview of various EMC terms and measuring conditions

A.7 Compatibility level and margin

From Clause A.3 to Clause A.6 it will be clear that it is often difficult, if not 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 5, 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 5.2 and 5.3, and already discussed in 5.2.2, might be determined along the following (idealised) lines.

If one considers a certain type of electromagnetic disturbance, at a certain value of the independent variable (see 5.3), assumes that the associated probability densities $p(D)$ of the disturbance level and $p(l)$ of the immunity level are known and in addition assumes that the condition for EMC is given by $(l – D) > 0$ in order to find the probability C that $(l – D) > 0$, i.e. $C = P\big((I - D) > 0\big)$, then the probability density $p(I – D)$ is calculated first. After that the probability $C = P\big((I - D) > 0\big)$ 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 $p(I)$.



The area C under the curve $p(I – D)$ for values $(I – D) > 0$ gives the probability of having EMC at the values of the independent variable under consideration

Figure A.4 – Examples of probability densities $p(D)$, $p(I)$ and the resulting $p(I – D)$

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 specified emission limit(s), and $p(I)$ and the specified 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 5.2.2 and 5.3. 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 (electromagnetic) compatibility level reads (see 3.1.1): "specified electromagnetic disturbance level used as a reference level for co-ordination in the setting of emission and immunity limits".

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.

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.