

TECHNICAL REPORT

BASIC EMC PUBLICATION

**Electromagnetic compatibility (EMC) –
Part 5-1: Installation and mitigation guidelines – General considerations**

IECNORM.COM : Click to view the full PDF of IEC TR 61000-5-1:2023



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2023 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

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

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

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IECNORM.COM : Click to view the full PDF of IEC 6005-1:2023

TECHNICAL REPORT

BASIC EMC PUBLICATION

**Electromagnetic compatibility (EMC) –
Part 5-1: Installation and mitigation guidelines – General considerations**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.100.01

ISBN 978-2-8322-6481-2

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	3
INTRODUCTION.....	5
1 Scope.....	6
2 Normative references	6
3 Terms, definitions, and abbreviated terms	6
3.1 Terms and definitions.....	6
3.2 Abbreviated terms.....	9
4 Electromagnetic phenomena.....	9
4.1 Overview of electromagnetic phenomena	9
4.2 Interference model.....	12
4.3 Consideration of electromagnetic phenomena in EMC standards	13
4.4 Approaches for ensuring EMC.....	13
5 EMC measures	16
5.1 General.....	16
5.2 Performance reason.....	16
5.3 Compatibility reasons.....	16
5.4 Types of measures	16
5.5 Measures at equipment level	17
5.6 Measures at system level.....	18
5.7 Protection versus immunity	19
5.8 Assessment of the need for mitigation methods	19
5.9 Radiated phenomena	19
5.10 Conducted phenomena	19
5.11 Design and installation of protective means	19
5.12 Evaluation of quality of installations	20
5.13 Verification of EMC	20
Annex A (informative) Overview of the publications in the IEC 61000-5 series	21
Bibliography.....	26
Figure 1 – The basic form of an EMI problem.....	13
Figure 2 – Principle of global protection by single barrier	14
Figure 3 – Principle of global protection by multiple barriers	14
Figure 4 – Principle of distributed protection	15
Figure 5 – Representation of equipment ports interfacing with the electromagnetic environment.....	18
Table 1 – Principal phenomena causing electromagnetic disturbances	11
Table A.1 – Overview of the IEC 61000-5 series (IEC TR 61000-5-2 to IEC 61000-5-10)	21

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –**Part 5-1: Installation and mitigation guidelines –
General considerations****FOREWORD**

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

IEC TR 61000-5-1 has been prepared by IEC technical committee 77: Electromagnetic compatibility. It is a Technical Report.

It forms Part 5-1 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 1996. This edition constitutes a technical revision.

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

- a) restructuring of clauses and subclauses with amending of technical content;
- b) alignment of the terminology with other parts of the IEC 61000 series, for example with IEC TR 61000-2-5;
- c) addition of an overview regarding the IEC 61000-5 series in Annex A.

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

Draft	Report on voting
77/585/DTR	77/588/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.

IECNORM.COM : Click to view the full PDF of IEC TR 61000-5-1:2023

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 parts which are to be published either as international standards or as technical specifications or as 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).

These parts of IEC 61000-5 will be published in chronological order and numbered accordingly.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 5-1: Installation and mitigation guidelines – General considerations

1 Scope

This part of IEC 61000-5, which is a technical report, covers general considerations and guidelines on mitigation methods aimed at ensuring electromagnetic compatibility (EMC) among electrical and electronic apparatus or systems used in industrial, commercial, and residential installations. This document is intended for use by all using and installing sensitive electrical or electronic installations and systems, and equipment with high emission levels that could degrade the overall electromagnetic (EM) environment. It applies primarily to new installations, but also applies during modifications or enhancements of legacy installations.

Specific topics, such as recommendations on the design and implementation of the earthing system, including the earth electrode and the earth network, the design and implementation of bonding apparatus or systems to earth or to the earth network, the selection and installation of appropriate cables, and the design and implementation mitigation means involving shielded enclosures, high-frequency filters, isolating transformers, surge-protective devices, etc., will be addressed in other parts of IEC 61000-5. Within this document the fundamental measures will be described.

The practices presented in this document address the EMC concerns of the installation, not the safety aspects of the installation nor the efficient transportation of power within the installation. Nevertheless, these two prime objectives are taken into consideration in the technical observations concerning EMC. These two primary objectives can be implemented concurrently for enhanced EMC of the installed sensitive apparatus or systems without conflict by applying the practices presented in this document and the relevant safety requirements. It is the responsibility of the designer and the installer to select the relevant technique most appropriate to a particular installation.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

3.1.1

bonding

act of connecting together exposed conductive parts and extraneous conductive parts of equipment, systems, or installations that are at essentially the same potential

3.1.2

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]

3.1.3

reference ground

part of the Earth considered as conductive, the electric potential of which is conventionally taken as zero, being outside the zone of influence of any earthing arrangement

Note 1 to entry: The concept "Earth" means the planet and all its physical matter.

[SOURCE: IEC 60050-195:2021, 195-01-01]

3.1.4

earth, verb

ground, verb US

to make an electric connection between a given point in a system or in an installation or in equipment and a local earth

Note 1 to entry: The connection to local earth can be

- intentional, or
- unintentional or accidental

and can be permanent or temporary.

[SOURCE: IEC 60050-195:2021, 195-01-08, modified – in the definition "a conductive part" has been replaced with "a given point in a system or in an installation or in equipment".]

3.1.5

earth electrode

ground electrode, US

conductive part, which may be embedded in the soil or in a specific conductive medium, for example concrete or coke, in electric contact with the earth

3.1.6

earthing network

conductors of the earthing system, not in contact with the soil, connecting apparatus, systems, or installations to the earth electrode or to other means of earthing

3.1.7

earthing system

three-dimensional electrical circuit which performs the earthing

Note 1 to entry: The earthing system includes two parts: the earth electrode and the earthing network.

3.1.8

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 term "device" has been added to the definition.]

3.1.9

(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]

3.1.10

facility

building or piece of equipment (like a hospital, factory, machinery, etc.) that is built, constructed, installed or established to perform some particular functions or to serve or facilitate some particular end

3.1.11

low frequency

LF

frequency up to and including 9 kHz

[SOURCE: IEC 60050-161:2014, 161-01-26]

3.1.12

high frequency

HF

frequency above 9 kHz

[SOURCE: IEC 60050-161:2014, 161-01-25]

3.1.13

immunity margin

ratio of the immunity limit to the electromagnetic compatibility level

[SOURCE: IEC 60050-161:1990, 161-03-16]

3.1.14

immunity level

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

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

3.1.15

point of common coupling

PCC

point of a power supply network, electrically nearest to a particular load, at which other loads are, or may be, connected

Note 1 to entry: These loads can be either devices, equipment or systems, or distinct customer's installations.

Note 2 to entry: In some applications, the term "point of common coupling" is restricted to public networks.

[SOURCE: IEC 60050-161:1990, 161-07-15]

3.1.16**in-plant point of coupling****IPC**

point of coupling inside the system or installation to be studied

3.1.17**port**

particular interface of the specified equipment with the external electromagnetic environment

Note 1 to entry: In some cases different ports can be combined.

3.2 Abbreviated terms

AC	alternating current
CB	citizen band
CW	continuous wave
DC	direct current
EM	electromagnetic
EMC	electromagnetic compatibility
ESD	electrostatic discharge
GSM	global system for mobile communication
HEMP	high altitude electromagnetic pulse
HF	high frequency
HPEM	high power electromagnetic pulse
IEMI	intentional electromagnetic interference
IPC	in-plant point of coupling
LEMP	lightning electromagnetic pulse
LF	low frequency
PCC	point of common coupling
PLT	power line telecommunications
RF	radio frequency
RFID	radio-frequency identification

4 Electromagnetic phenomena**4.1 Overview of electromagnetic phenomena**

Any equipment, system or installation that transmits, distributes, processes, or otherwise utilises any form of electrical energy can be source of electromagnetic interference, if any aspect of its operation generates electromagnetic disturbance that results in a degradation of performance of any neighbouring equipment, system, or installation.

The classification of electromagnetic disturbances can be undertaken in several ways. For the purpose of this document, the classification is underpinned by the following:

- the variation of the electromagnetic disturbance signal amplitude as a function of frequency; and
- the propagation means of the disturbance either as conducted or radiated.

The application of the above criteria results in the following categories of electromagnetic disturbances that are considered in EMC work:

- low-frequency conducted phenomena (e.g., harmonics, voltage dips and fluctuations);
- low-frequency radiated phenomena (e.g., magnetic fields at power frequency);
- high-frequency conducted phenomena (e.g., fast transients);
- high-frequency radiated phenomena (e.g., electromagnetic fields);
- electrostatic discharges (ESD).

To ensure EMC, equipment, systems and installations are required to cope with the disturbing effects of electromagnetic phenomena independent of their origin. Table 1 gives an overview of electromagnetic phenomena which can occur at a particular location. These electromagnetic phenomena need to be considered in the design and installation of the equipment or system in order to ensure electromagnetic compatibility.

IECNORM.COM : Click to view the full PDF of IEC TR 61000-5-1:2023

Table 1 – Principal phenomena causing electromagnetic disturbances

LF phenomena	Power supply networks	Harmonics/Inter-harmonics
		Voltage fluctuations
		Voltage dips
		Voltage interruptions
		Voltage unbalance
		Voltage frequency variations
		Common mode voltages
		Signalling voltage (0,1 kHz to 3 kHz)
		Induced LF
		DC in AC networks
		Differential mode voltages
	Signal and control cables	Induced LF (normal conditions)
		Induced LF (fault conditions)
	LF magnetic field	DC
		Railway
		Power system
		Power system harmonics (n = harmonics)
		Not power system related
	LF electric field	DC lines
		Railway (16 2/3 Hz)
		Power system (50 Hz/ 60 Hz)
HF phenomena	Signalling voltage/PLT	3 kHz to 95 kHz / 95 kHz to 148,5 kHz / 148,5 kHz to 500 kHz
	Direct-conducted CW/PLT (intentional)	1,606 5 MHz to 87,5 MHz
	Direct-conducted CW (unintentional)	9 kHz to 150 kHz
	HF-conducted induced CW	10 kHz to 150 kHz / 0,15 kHz to 150 MHz
	Unidirectional transients	Nanoseconds
		Microseconds, close
		Microseconds, distant
		Milliseconds
	HF-conducted oscillatory transients	Low, medium, high frequency
	HF radiated	
	Radiated CW	ISM Group 2
	Radiated modulated	Mobile units/GSM/DCS 1800/DECT
		Base stations
		Digital television broadcast
		Unlicensed radio services
		Paging services (base station)
		RFID + railway transponder
		Other RF items
		Amateur radio stations
		CB
		Wireless LAN
		Bluetooth, Zigbee, LoraWan ¹ , etc
	Radiated pulsed	Radiated transients
		RADAR
	ESD	Slow/Fast
	High altitude electromagnetic pulse (HEMP)	Not considered in this document; for further information see relevant parts of the IEC 61000-5 series as described in Annex A.
	High power electromagnetic pulse (HPEM)	Not considered in this document; for further information see relevant parts of the IEC 61000-5 series as described in Annex A.

Depending on the electromagnetic environment of an installation site and for a given phenomenon, there is a high probability of having a certain level of electromagnetic disturbances. According to the concepts of electromagnetic environment classification (see IEC TR 61000-2-5), a determined (or specified) compatibility level will be determined or specified. Furthermore, each apparatus has an intrinsic immunity level that can be sufficient in view of the disturbances occurring on the site. As environmental conditions and performance criteria for immunity of apparatus can vary for each installation, the information given in the IEC 61000-5 series will serve as recommendations.

The sources of electromagnetic disturbances and their main characteristics are described in detail in IEC TR 61000-2-5. IEC TR 61000-2-5 as well as the other parts of the IEC 61000-2 series contain a set of tables for selecting appropriate disturbance degrees as compatibility levels for the electromagnetic phenomena to be expected at the location of interest.

The following specific points are listed in connection with the general listing of Table 1:

- a) The ESD phenomenon is considered as a combined phenomenon (conducted and radiated). Its occurrence is greatly influenced by physical characteristics of the local environment (floor covering, worker's clothing, atmospheric conditions, etc.). Mitigation of ESD effects is not included in the scope of this document.
- b) High altitude electromagnetic pulse (HEMP) is a very specific phenomenon which is not included in the scope of this document, although some high frequency mitigation guidelines are useful to reduce the impact of disturbances.
- c) Disturbances can be direct or indirect.
 - Direct disturbances:
 - radiated: an external field radiates on the sensitive susceptor;
 - conducted: the source is connected to the installation.
 - Indirect disturbances:
 - radiated: a field exists after penetrating a shield and radiates on the sensitive electronics;
 - conducted: an electromagnetic field can induce currents or voltages into conductors that can be within the installation.
- d) Transient voltages appearing downstream of protective devices can also be a source of disturbances in some cases.
- e) The effects of lightning electromagnetic pulse (LEMP) are included in the conducted and radiated phenomena listed in Table 1, which are grouped by their physical characteristics rather than the specific source (excluding the ESD and HEMP phenomena mentioned in Table 1). Thus, there is no special entry for the LEMP source.
- f) Disturbances on equipment or system level.

4.2 Interference model

Electromagnetic disturbances are caused by conducted or radiated phenomena. Figure 1 depicts in a general manner how EM disturbances can affect sensitive apparatus; Figure 1 illustrates a model that compromises an emitter, a coupling path, and a susceptor. The emitter can be either conducted voltage or current, or an electric or magnetic field propagated through space. An apparatus can be both an emitter and susceptor. Further details with regards the interference model are provided in IEC TR 61000-1-1.

¹ Bluetooth, Zigbee and LoraWan are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of these products.

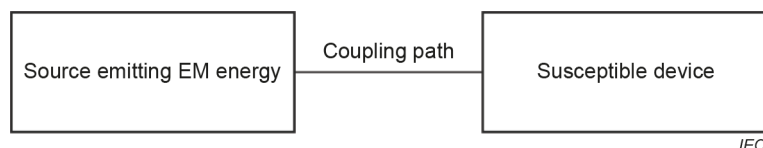


Figure 1 – The basic form of an EMI problem

4.3 Consideration of electromagnetic phenomena in EMC standards

Different types of standards are available to define conditions for compliance with EMC requirements for electrical and electronic products:

- dedicated product standards;
- product family standards;
- generic standards; and
- basic standards.

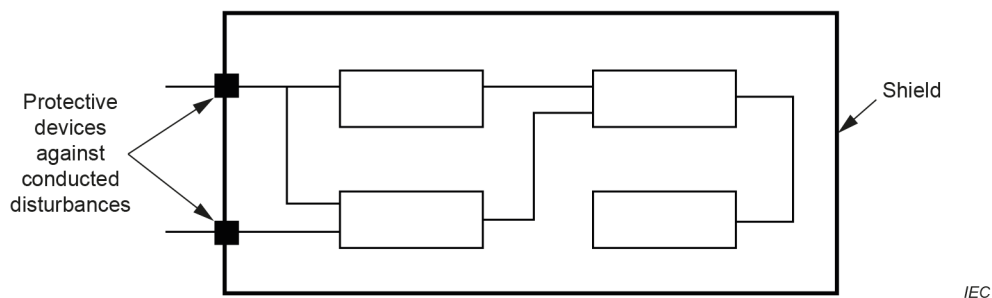
The definitions and characteristics of these standards have been established by the Advisory Committee on Electromagnetic Compatibility (ACEC). One essential aspect of a standard is the availability of suitable tests to verify compliance with the standard. In the case of an installation, however, testing the complete installation is generally not practical or appropriate, when EMC for sensitive installations and systems is concerned. Therefore, installation guidelines are necessary to adapt to a maximum of situations. There are many types of installations and successful EMC has been achieved through different approaches. Thus, this document recommends a general approach, while not precluding other approaches if appropriate. Special mitigation methods might not be necessary when the equipment satisfies applicable emissions and immunity standards.

4.4 Approaches for ensuring EMC

The process adopted for ensuring electromagnetic compatibility of installations is dependent on how early in the design life cycle the EMC specialist is offered an opportunity to contribute. There are two main approaches:

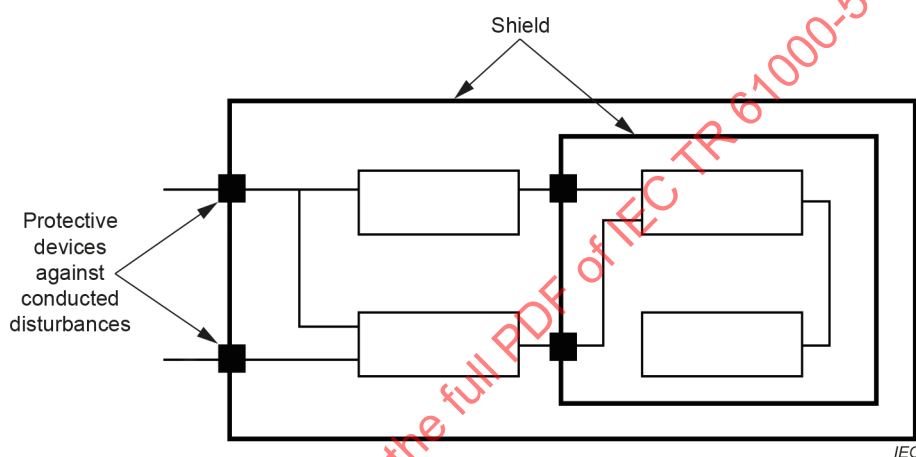
- a) At the early stages of a major installation, each compatibility level (specific for a given electromagnetic disturbance) can be assigned for the particular environment of the installation. Through specification of overall mitigation schemes, the apparatus and its installation practice are then specified with immunity and emission levels corresponding to the predetermined compatibility level.
- b) At later stages of the design, for the installation of additional apparatus or the initial installation of commercially available apparatus for which no opportunity exists to modify its EMC characteristics, a mismatch can occur between the overall, *de facto* compatibility level of the site and the capability of the apparatus. In such a case, mitigation methods can be selected to close the gap between the environment and the apparatus immunity levels to a minimum.

The first approach has been successfully applied for installations where a single engineering entity has the authority to specify and enforce a certain compatibility level. As a general principle, this approach is illustrated by the global protection topology of Figure 2 and Figure 3. A concrete example of this very successful approach is the insulation coordination of high-voltage apparatus applied by electric utilities where the maximum overvoltage level to be expected is determined by the prior choice of surge arresters, followed by specification of the apparatus with an insulation level consistent with the protective level provided by the arresters.



NOTE According to the principle of a single barrier, mains filters, surge-protective devices and a shield protect the whole installation. No specific protection is applied to the individual units except when internally generated disturbances exist.

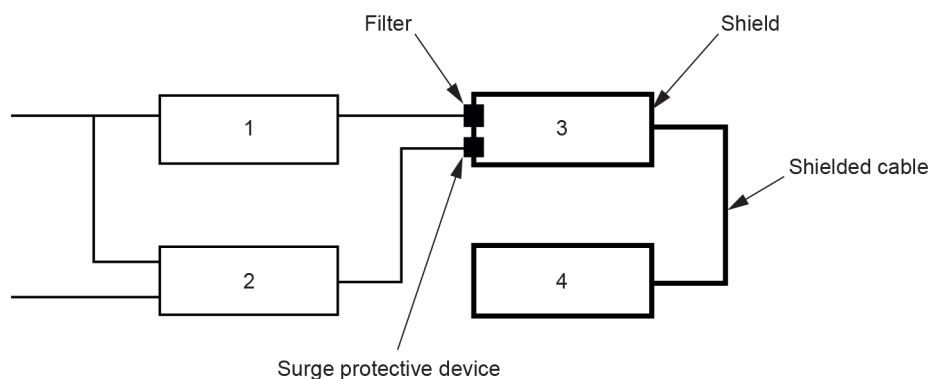
Figure 2 – Principle of global protection by single barrier



NOTE According to the principle of multiple barriers, no specific protection is applied to the individual units, but there is a cascading of multiple electromagnetic barriers according to the susceptibility level(s) of the units.

Figure 3 – Principle of global protection by multiple barriers

The second approach is generally applied in existing installations where the owner or designer lacks the leverage to impose a predetermined compatibility level for the environment or immunity/emission level for the apparatus. Figure 4 shows the typical topology associated with this approach. This situation is encountered in low-voltage, end-user commercial or industrial facilities, and in residential environments.



NOTE According to the principle of distributed protection, units 1 and 2 are not protected, only units 3 and 4 which contain sensitive electronics are protected by using specific enclosures, filters, or protective devices and shielded cables. Examples of such protection for small and large systems are given in Annex A.

Figure 4 – Principle of distributed protection

In this second approach, the task of the EMC specialist then becomes one of matching the equipment and environment after the fact. In favourable cases, this matching can still be done before problems occur – the very purpose of the documents of the IEC 61000-5 series is indeed to make this matching happen. However, this approach is often applied to correct problems after they have occurred. This approach is not the most cost-effective or time-effective method.

Regardless of the applicable approach, several steps can be taken. The sequence of the steps depends on the approach selected, as shown below.

Approach a):

- 1) environment characterization
- 2) specification of mitigation method
- 3) evaluation of mitigation performance
- 4) specification of apparatus immunity/emissions
- 5) verification of apparatus immunity/emissions
- 6) verification of EMC (if possible)

Approach b):

- 1) environment characterization
- 2) passive acceptance of apparatus immunity
- 3) identification of mismatch
- 4) specification of mitigation method
- 5) evaluation of the quality of installations
- 6) verification of EMC (if possible)

5 EMC measures

5.1 General

In any given installation, depending on the environment, the number and type of installed apparatus, cables used, and installation methods can result in a variety of disturbances. As described in 4.4, the existence of disturbances is inherent in any electrical apparatus. Furthermore, each apparatus has an intrinsic immunity against external disturbances. The level of mitigation and the level of external disturbances can lead to an unbalanced disturbance level within the apparatus. This nonconformity to electromagnetic disturbances can prevent the apparatus from working as intended.

The aim of each EMC mitigation measure is to reduce the disturbance that would reach other equipment so that it is less than the equipment immunity level (for that particular phenomenon).

All electromagnetic disturbances can be classified according to the following:

- frequency range;
- propagation mode;
- behaviour in the time domain (e.g. dwell time, rise/fall time).

5.2 Performance reason

One aim resulting from the need to ensure EMC is to guarantee the performance of each individual apparatus. By defining a permissible limit for emission, the whole environment can be described with known permissible limits for each type of disturbance. If the immunity of an apparatus is higher than the permissible limit for emission of the installations, the system will work without degradation. To guarantee this performance it needs to be ensured, that

- the maximum emission of the installation is below a defined level;
- the immunity of each individual apparatus is higher than the maximum emission expected from the installation.

If the maximum emission cannot be guaranteed due to, for example, a function of an apparatus within the installation resulting in higher emissions than normally allowed, the susceptibility level of all other installations need to be elevated to meet the compatibility level.

5.3 Compatibility reasons

If an environment is not known, or it is not certain if an apparatus can be used in a certain environment, some agreed compliance levels need to be guaranteed, for example, every radiating system, such as radio, GSM, etc., will generate emissions for proper function. Therefore, all other systems need to be designed to be compatible with these emissions.

On the other hand, all other equipment will not use, for example, the same frequencies as standardized transmission systems, so as not to interfere with them.

To ensure all equipment being brought to market works in its intended environment, it is expected to fulfil some compliance levels for a number of different phenomena.

5.4 Types of measures

To ensure EMC between different kinds of apparatus within an installation, some basic rules need to be followed. These rules, listed below, are applicable at the equipment or system level:

- reduce or eliminate any kind of unwanted emissions;
- reduce or eliminate any kind of coupling paths; and
- increase the immunity of the equipment.

5.5 Measures at equipment level

Each equipment is supposed to be adequately immune to electromagnetic disturbances expected in the intended application or installation. It is equally expected that such apparatus will generate minimum (unwanted) emission. For this reason, each apparatus needs to be designed to:

- reduce unwanted disturbances to the lowest (technical) possible level;
- incorporate basic functionality to mitigate external disturbances;
- implement measures that ensure the best EMC behaviour, for example grounding facilities on conducting surfaces, electrically closed enclosures, measures to deal with cable screens, etc.

Any apparatus classified as Electrical Protection Level 1 will normally have metallic or conductive enclosures, and as such provide clearly marked grounding connectors. If the whole surface can be used for grounding, this will equally be marked and mentioned in the documentation provided.

If special measures need to be implemented to obtain the electromagnetic compatibility, for example the use of shielded cable, etc., this needs to be clearly documented and made clear to the intended user or installer.

If an apparatus is emitting intentional frequencies, these need to be clearly marked on the apparatus. Ideally, the apparatus supplier states the apparatus immunity level(s). In case such information is not provided, there are three possibilities to derive the relevant information:

- a) The immunity level(s) is (are) specified in the relevant product standard(s), that have been properly documented.
- b) If no product standard exists, then the immunity level is obtained by implicit application of the relevant generic standard.
- c) If no test result is available then it is necessary to postulate a level taking into account the technologies used, based on measurements, manufacturer's data or publications. The validity of this postulate can be checked by application of the relevant parts of the IEC 61000-4 series concerning testing and measurement techniques.

To provide a transition from the overall concept of coupling between environment and apparatus to the detailed specifics, it is useful to consider the concept of ports. The various EM disturbances enter or exit the apparatus through these ports. By identifying such ports, protective steps can be specifically related to the nature of the EM phenomenon, its coupling path, and its impact on the functional elements of the apparatus (immunity) or its impact on the environment (emissions).

Figure 5 shows how ports can be identified for the entry of EM disturbances into an apparatus. From its initial definition in the case of an apparatus, this concept can be generalized to all cases, including systems and installations. Figure 5 shows the case of EM disturbances impinging on the apparatus through four ports.

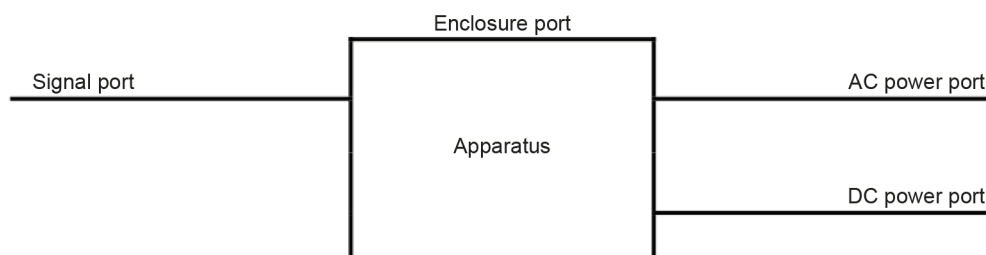


Figure 5 – Representation of equipment ports interfacing with the electromagnetic environment

Appropriate mitigation steps can be applied on every port of the apparatus (system, installation). For the AC and DC power ports, this protection typically involves the use of surge-protective devices, sometimes complemented by filters or specific cabling. For the signal ports, the protection might involve a shielded cable or a surge-protective device or a filter, or both.

In terms of the concept illustrated in Figure 5 the earth connection is not to be regarded as a separate port that interfaces with the electromagnetic environment. Nevertheless, the earthing of each apparatus can be an important component in mitigating EM disturbances, for example high frequency transients and frequencies. Therefore, the earthing is always regarded to reduce effects or disturbances.

The case of ESD disturbances is more complex because it involves different types of discharges. A discharge to the conductors and fed through any of the four conducted ports is a clear case of conducted disturbance. A discharge between two nearby objects but not involving the apparatus is a clear case of radiated disturbance. A discharge to a conductive envelope is complex because the envelope and its apertures become the radiators of fields created by the conducted discharge.

The IEC 61000-5 series addresses in detail the mitigation and installation practices with consideration of the relevant port(s) and the associated EM phenomena. IEC TR 61000-5-2 deals with the earth port and with the conductive ports, from the point of view of earthing and cabling. IEC TR 61000-5-6 deals with the enclosure port (shielding) and the conductive ports (filters, decoupling devices, and surge-protective devices).

5.6 Measures at system level

The connection of more than two apparatuses is called a system. Therefore, all installations comprising more than two apparatuses are treated as a system. One system can be integrated into other systems.

By designing a new system or retrofitting an existing system, the EMC measures at system level need to be considered. If appropriate and possible, it is advisable to separate systems into sub-systems.

One basic concept of each electromagnetic compliant system is not to interfere with the correct functioning of neighbouring systems. With respect to conducted disturbance the objective is to reduce the effectiveness of the coupling path. This is generally achieved by:

- implementing a structured cable management system by maintaining an appropriate distance between different functional cables;
- implementing a structured cable management system by using shielded cables where technically feasible;

- implementing low impedance bonding of cable shields at the entry point of each metallic enclosure.

5.7 Protection versus immunity

There are two general approaches to obtain EMC immunity for an installation, either by a global protection (Figure 2 and Figure 3) or by a distributed protection (Figure 4). In some cases, mitigation methods might not be necessary if the equipment has a sufficiently high immunity level, compared with the prevailing disturbance level.

5.8 Assessment of the need for mitigation methods

The attenuation provided by an electromagnetic barrier (shields, filters, etc.) is selected such that it is not less than the difference between the expected disturbance level and the immunity limit specified in the relevant IEC standard (or the immunity level of the equipment to be protected if it is known to be significantly higher than the immunity limit).

Uncertainties on disturbance level(s) and immunity level(s), and the attenuation can be dealt with by the selection of an appropriate margin. This margin could be large or small according to the criticality of the function fulfilled by the apparatus considered. See IEC TR 61000-1-1 for a discussion of the statistical aspects of margins in EMC considerations.

A numerical relation between disturbance level and immunity level can be established for most of the conducted and radiated phenomena involved. For cabling, shielding, filtering and protective devices, it is obtained by applying the concepts of shielding effectiveness, transfer impedance, insertion loss and residual voltage (see IEC TR 61000-5-2 and IEC TR 61000-5-6). Such a numerical relation is difficult to establish for earthing; it is a matter of good practice in the design and implementation of the earthing system.

5.9 Radiated phenomena

Different classes of shielding effectiveness can be defined. The appropriate class is selected by computing the difference between the disturbance level and immunity limit. In case of global protection, filters and other protective means at the point of penetration of the shield can be implemented in a manner that will not degrade the shielding effectiveness.

5.10 Conducted phenomena

Two parameters are used for dealing with continuous-wave phenomena: transfer impedance for cables and connectors (see IEC TR 61000-5-2) and insertion loss for filters (see IEC TR 61000-5-6). Three parameters are used for transient phenomena, the preceding two, plus residual voltage of surge-protective devices.

The necessary insertion loss is determined either by considering the difference between disturbance level and immunity limit, or by taking into consideration the emission limits that the apparatus will satisfy in compliance with applicable emission standards.

The selection of overvoltage protection schemes depends on the susceptibility level of the equipment they are intended to protect, as well as on the overvoltage/overcurrent disturbances that the protective device will mitigate or divert (see IEC TR 61000-5-6).

5.11 Design and installation of protective means

Requirements for mitigation methods need to be written in terms of practical implementation. This is achieved on the basis of experience, measurements, or vendor data.

5.12 Evaluation of quality of installations

All apparatuses making up an installation have their own performance characteristics. The goal of installation guidelines is first to maintain these characteristics, and even to improve them. The method of installation is selected such that it does not degrade the EMC performance of the apparatus. Precise performance criteria of a complex installation are difficult to define and evaluate but nevertheless they are recommended to correspond to the testing and measurement techniques set forth in the IEC 61000-4 series.

5.13 Verification of EMC

Because numerical evaluation is not always possible, especially for a complex installation, at least a checklist of the appropriate measures can be established. This checklist can be used for a proposed design, a completed installation, and also as a baseline when troubleshooting an existing installation. For an existing (new or old) installation, a visual verification can be performed and, if necessary, measurements can be performed where site conditions allow.

IECNORM.COM : Click to view the full PDF of IEC TR 61000-5-1:2023

Annex A (informative)

Overview of the publications in the IEC 61000-5 series

As this document intends to describe some general considerations related to installation and mitigation, it does not contain detailed information about all electromagnetic phenomena nor does it consider particular installation practices. However, some specific mitigation information is available in IEC TR 61000-5-2 for general EMC applications. In other parts of the IEC 61000-5 series, specific mitigation measures are discussed for the transient EM phenomena of HEMP, HPEM and IEMI, as these mainly high frequency disturbances are so severe that it is not generally possible to protect equipment to their full disturbance levels. For this reason, work was done to determine the best mitigation methods at the installation level to reduce the radiated and conducted transient disturbances to levels that typical electronic equipment inside the installation could tolerate. It is noted that for the mitigation documents dealing with HEMP and HPEM, many of the mitigation measures discussed in these documents will also work for other phenomena that cover the same frequency range as the time-domain transients.

Table A.1 gives an overview of documents of the IEC 61000-5 series (apart from this document), which deal with the mitigation of particular electromagnetic phenomena in detail. It is noted that most of the installation mitigation techniques are aimed at high frequency ($f > 9$ kHz) phenomena, although a few are applicable to low frequency applications ($f < 9$ kHz).

Table A.1 – Overview of the IEC 61000-5 series (IEC TR 61000-5-2 to IEC 61000-5-10)

Publication	Title and short description	Electromagnetic phenomena	Frequency range
IEC TR 61000-5-2	Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling This document covers guidelines for the earthing and cabling of electrical and electronic systems and installations aimed at ensuring EMC among electrical and electronic apparatus or systems. More particularly, it is concerned with earthing practices and with cables used in industrial, commercial, and residential installations. It is intended for use by installers and users, and to some extent, manufacturers of sensitive electrical or electronic installations and systems, and equipment with high emission levels that could degrade the overall electromagnetic environment. It applies primarily to new installations, but where economically feasible, it may be applied to extensions or modifications to existing facilities.	Earthing Cabling All low frequency conducted disturbances All high frequency conducted disturbances	$f < 9$ kHz $f > 9$ kHz (All frequencies)

Publication	Title and short description	Electromagnetic phenomena	Frequency range
IEC TR 61000-5-3	Electromagnetic compatibility (EMC) – Part 5-3: Installation and mitigation guidelines – HEMP protection concepts This document provides elements for the design of an adequate protection for civil facilities against the electromagnetic pulse due to a high altitude nuclear explosion, denoted in what follows by HEMP, for the evaluation of already existing protections with respect to stresses imposed by HEMP, to compare the requirements of HEMP and lightning protection in order to show if they can be combined at low cost, and to emphasise the differences between the requirements of HEMP and lightning protections in order to permit the evaluation of the consequences of HEMP when no additional measures are taken except existing lightning protection.	Radiated and conducted disturbances: • HEMP • Lightning	$f > 9 \text{ kHz}$
IEC TR 61000-5-4	Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 4: Immunity to HEMP – Specifications for protective devices against HEMP radiated disturbance. This document defines how protective devices for High Altitude Electromagnetic Pulse (HEMP) protection of civilian systems are specified. Performance requirements will be given in future IEC standards. This technical report is intended to be used for the harmonization of existing or future specifications issued by protective devices manufacturers, electronic equipment manufacturers, administrative bodies and other buyers. This technical report covers protective devices currently used for protection against HEMP radiated EM fields. In general, parameters relevant to HEMP, that is parameters related to very fast changes of EM fields, as a function of time, are dealt with.	Radiated disturbances: • HEMP	$f > 9 \text{ kHz}$
IEC 61000-5-5	Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 5: Specification of protective devices for HEMP conducted disturbance This document defines how protective devices for conducted disturbance proposed for HEMP protection shall be specified. It is intended to be used for the harmonization of existing or future specifications issued by protective device manufacturers, electronic equipment manufacturers, administrations and other ultimate buyers. Performance requirements shall be given in future IEC documents. This publication covers protective devices currently being used for protection against induced HEMP transients on signal and low voltage power lines (nominal voltage up to 1 kV a.c.). General information can be applied also to high voltage lines. However, in these cases, the additional requirements for the protection levels of existing lightning arresters (especially gapless MO-arresters) are under consideration.	Conducted disturbances: • HEMP	$f > 9 \text{ kHz}$