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REDLINE VERSION

TECHNICAL REPORT

BASIC EMC PUBLICATION

Electromagnetic compatibility (EMC) –
Part 2-5: Environment – Description and classification of electromagnetic environments

colour inside

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 2-5: Environment – Description and classification of electromagnetic environments

FOREWORD

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The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 61000-2-5, which is a technical report, has been prepared by technical committee 77: Electromagnetic compatibility.

It forms Part 2-5 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This third edition cancels and replaces the second published in 2011. This edition constitutes a technical revision.

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

a) the description of the radiated electromagnetic environment has been updated taking into account recent communication technologies;
b) some conducted phenomena and respective interference sources have been described in more detail.

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

Enquiry draft	Report on voting
77/525A/DTR	77/526/RVC

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

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The reader's attention is drawn to the fact that Annex E lists some “in-some-country” clauses on differing practices regarding a particular electromagnetic phenomenon.

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 "http://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- withdrawn,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.

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 2-5: Environment – Description and classification of electromagnetic environments

1 Scope ~~and object~~

Knowledge of the electromagnetic environment that exists at locations where electrical and electronic equipment and systems are intended to be operated is an essential precondition in the process of achieving electromagnetic compatibility. This knowledge can be obtained by various approaches, including a site survey of an intended location, the technical assessment of the equipment and system, as well as the general literature.

This part of IEC 61000

- introduces the concept of disturbance degrees and defines these for each electromagnetic phenomena,
- classifies into various location classes and describes them by means of attributes,
- provides background information on the different electromagnetic phenomena that may exist within the environment and
- compiles tables of compatibility levels for electromagnetic phenomena that are considered to be relevant for those location classes.

This part of IEC 61000 is intended for guidance for those who are in charge of considering and developing immunity requirements. It also gives basic guidance for the selection of immunity levels. The data are applicable to any item of electrical or electronic equipment, sub-system or system that operates in one of the locations as considered in this document.

NOTE 1 This document considers relevant electromagnetic phenomena when describing and classifying electromagnetic environments (except HEMP and HPEM which are covered in other IEC 61000-2 standards). It makes use of the specification of technologies, of published data and of results from measurements. Not all electromagnetic phenomena considered here are described in detail in this document, but rather in other documents of the IEC 61000-2 series from which the relevant information and data are taken and used in this document. For more detailed information about those phenomena the user is referred to this series. See also Annex F for an overview of the various parts of the IEC 61000-2 series.

NOTE 2 It ~~should be~~ is noted that immunity requirements and immunity levels determined for items of equipment which are intended to be used at a certain location class are not inevitably bound to the electromagnetic environment present at the location, but also to requirements of the equipment itself and the application in which it is used (e.g. when taking into account requirements regarding availability, reliability or safety). These could lead to more stringent requirements with respect to immunity levels or with respect to applicable performance criteria. These levels ~~may~~ can also be established for more general purposes such as in generic and product standards, taking into account statistical and economic aspects as well as common experience in certain application fields.

NOTE 3 Electromagnetic phenomena in general show a broad range of parameters and characteristics and hence cannot be related one-to-one to standardized immunity tests which basically reflect the impact of electromagnetic phenomena by a well described test setup. Nonetheless, this document follows an approach to correlate electromagnetic phenomena and standardized immunity tests up to a certain extent. This might allow users of this document to partly take into account standardized immunity tests such as given for example in IEC 61000-4 (all parts), when specifying immunity requirements.

The descriptions of electromagnetic environments in this document are predominantly generic ones, taking into account the characteristics of the location classes under consideration. Hence, it should be kept in mind that there might be locations for which a more specific description is required in order to conclude on immunity requirements applicable for those specific locations.

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 – Chapter 161: Electromagnetic compatibility* (available at www.electropedia.org)
~~Amendment 1 (1997)~~
~~Amendment 2 (1998)~~

~~IEC 60118-4:2006, *Electroacoustics – Hearing aids – Part 4: Induction loop systems for hearing aid purposes – Magnetic field strength*~~

~~IEC 60364-4-44:2007, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*~~

~~IEC/TR 61000-1-4:2005, *Electromagnetic compatibility (EMC) – Part 1-4: General – Historical rationale for the limitation of power-frequency conducted harmonic current emissions from equipment, in the frequency range up to 2 kHz*~~

IEC 61000-2-2~~:2002~~, *Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*

IEC TR 61000-2-3~~:1992~~, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 3: Description of the environment – Radiated and non-network-frequency-related conducted phenomena*

IEC 61000-2-4~~:2002~~, *Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances*

IEC TR 61000-2-8~~:2002~~, *Electromagnetic compatibility (EMC) – Part 2-8: Environment – Voltage dips and short interruptions on public electric power supply systems with statistical measurement results*

IEC 61000-2-9~~:1996~~, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 9: Description of HEMP environment – Radiated disturbance*

IEC 61000-2-12~~:2003~~, *Electromagnetic compatibility (EMC) – Part 2-12: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public medium-voltage power supply systems*

IEC 61000-2-13~~:2005~~, *Electromagnetic compatibility (EMC) – Part 2-13: Environment – High-power electromagnetic (HPEM) environments – Radiated and conducted*

~~IEC 61000-3-12:2004, *Electromagnetic compatibility (EMC) – Part 3-12: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤75 A per phase*~~

IEC 61000-4-2~~:2008~~, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3~~:2006~~, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
~~Amendment 1 (2007)~~
~~Amendment 2 (2010)~~

IEC 61000-4-4~~:2004~~, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*
~~Amendment 1 (2010)~~

IEC 61000-4-5~~:2005~~, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6~~:2008~~, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8~~:2009~~, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-9~~:1993~~, *Electromagnetic compatibility (EMC) – Part 4-9: Testing and measurement techniques –~~ Pulse~~ Impulse magnetic field immunity test*
~~Amendment 1 (2000)~~

IEC 61000-4-10~~:1993~~, *Electromagnetic compatibility (EMC) – Part 4-10: Testing and measurement techniques – Damped oscillatory magnetic field immunity test*
~~Amendment 1 (2000)~~

IEC 61000-4-11~~:2004~~, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-12~~:2006~~, *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Ring wave immunity test*

IEC 61000-4-13~~:2002~~, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests*
~~Amendment 1 (2009)~~

IEC 61000-4-14~~:1999~~, *Electromagnetic compatibility (EMC) – Part 4-14: Testing and measurement techniques – Voltage fluctuation immunity test for equipment with input current not exceeding 16 A per phase*
~~Amendment 1 (2001)~~
~~Amendment 2 (2009)~~

IEC 61000-4-16:~~1998~~ 2015, *Electromagnetic compatibility (EMC) – Part 4-16: Testing and measurement techniques – Test for immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz*
~~Amendment 1 (2001)~~
~~Amendment 2 (2009)~~

IEC 61000-4-18~~:2006~~, *Electromagnetic compatibility (EMC) – Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test*
~~Amendment 1 (2010)~~

IEC 61000-4-19, *Electromagnetic compatibility (EMC) – Part 4-19: Testing and measurement techniques – Test for immunity to conducted, differential mode disturbances and signalling in the frequency range 2 kHz to 150 kHz at a.c. power ports*

IEC 61000-4-27:2000, *Electromagnetic compatibility (EMC) – Part 4-27: Testing and measurement techniques – Unbalance, immunity test for equipment with input current not exceeding 16 A per phase*
Amendment 1 (2009)

IEC 61000-4-28:1999, *Electromagnetic compatibility (EMC) – Part 4-28: Testing and measurement techniques – Variation of power frequency, immunity test for equipment with input current not exceeding 16 A per phase*
Amendment 1 (2001)
Amendment 2 (2009)

CISPR/TR 16-4-1:2009, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-1: Uncertainties, statistics and limit modelling – Uncertainties in standardized EMC tests*

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.

NOTE For brevity, instead of repeating the wording "device, equipment or system", the term "item" is used in this report.

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
active infeed converter
AIC
self-commutated electronic power converter of all technologies, topologies, voltages and sizes which is connected between the AC power supply network (lines) and usually a stiff DC side (current source or voltage source) and which can convert electric power in both directions (generative or regenerative) and control the reactive power or the power factor

Note 1 to entry: Some active infeed converters can additionally control the harmonics to reduce the distortion of an applied AC voltage or current.

3.1.2
blackout
cutoff of electrical power, especially as a result of shortage, mechanical failure, or overuse by consumers

EXAMPLE A power cut due to a short- or long-term electric power loss in an area.

3.1.3
brownout
reduction or cutback in electric power, especially as a result of shortage, mechanical failure, or overuse by consumers

EXAMPLE Reduction in the voltage of commercially supplied power. It is caused by the failure of the generation, transmission, or distribution system, or deliberately by the power utility when demand exceeds supply. The consumer may or may not notice the difference. In the worst case, damage may result.

3.1.4
burst
sequence of a limited number of distinct pulses or an oscillation of limited duration

[SOURCE: IEC 60050-161:1990, 161-02-07]

3.1.5
burst (in TDMA)
signals transmitted by a terminal in the form of a block of predetermined structure during a time interval allotted to the terminal by a TDMA protocol

[SOURCE: IEC 60050-725:1994, 725-14-15]

3.1.6
characteristic impedance of a medium
wave impedance for a travelling wave in a specific medium

Note 1 to entry: The characteristic impedance of a homogeneous isotropic medium is given by ~~η_t = sqrt (μ/ε)~~

$$\eta_t = \sqrt{\frac{\mu}{\varepsilon}},$$

where

μ is the permeability of the homogeneous isotropic medium, and

ε is the permittivity of the homogeneous isotropic medium.

[SOURCE IEC 60050-705:1995, 705-03-23, modified – the formula for characteristic impedance has been simplified.]

3.1.7
commercial, public and light-industrial location
location which exists as areas of the city centre, offices, public transport systems (road/train/underground), and modern business centres containing a concentration of office automation equipment (PCs, fax machines, photocopiers, telephones, etc.), and characterized by the fact that equipment is directly connected to a low-voltage public mains network or connected to a dedicated DC source which is intended to interface between the equipment and the low-voltage mains network

EXAMPLE Examples of commercial, public or light-industrial locations are:

- retail outlets, for example shops, supermarkets;
- business premises, for example offices, banks, hotels, data centers;
- areas of public entertainment, for example cinemas, public bars, dance halls;
- places of worship, for example temples, churches, mosques, synagogues;
- outdoor locations, for example petrol stations, car parks, amusement and sports centers;
- general public locations, for example park, amusement facilities, public offices;
- hospitals, educational institutions, for example schools, universities, colleges;
- public traffic area, railway stations, and public areas of an airport;
- light-industrial locations, for example workshops, laboratories, service centers.

Note 1 to entry: The connection between location and electromagnetic environment is given in 3.1.15.

3.1.8
(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 mmunity 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]

3.1.9
disturbance degree
specified and quantified intensity within a range of disturbance levels corresponding to a particular electromagnetic phenomenon encountered in the environment of interest

3.1.10
disturbance level
amount of magnitude of an electromagnetic disturbance, measured and evaluated in a specified way

3.1.11
earth port
cable port other than signal, control or power port, intended for connection to earth

3.1.12
electric field
constituent of an electromagnetic field which is characterized by the electric field strength E together with the electric flux density D

[SOURCE: IEC 60050-121:1998, 121-11-67]

3.1.13
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 60050-161:1990, 161-01-07, modified – the terms "device" and "equipment" have been added to the definition.]

3.1.14
electromagnetic disturbance
any electromagnetic phenomenon which ~~may~~ 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~~ can be electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

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

3.1.15
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 may need a statistical approach.

Note 2 to entry: It is very important not to confuse the electromagnetic environment and the location itself.

[SOURCE: IEC 60050-161:1990, 161-01-01, modified – a Note 2 to entry has been added.]

3.1.16
electromagnetic field
field, determined by a set of four interrelated vector quantities, that characterizes, together with the electric current density and the volumic electric charge, the electric and magnetic conditions of a material medium or of vacuum

Note 1 to entry: The four interrelated vector quantities, which obey Maxwell Equations, are by convention:

- the electric field strength, E,
- the electric flux density, D,
- the magnetic field strength, H,
- the magnetic flux density, B.

[SOURCE: IEC 60050-121:1998, 121-11-61]

3.1.17
(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]

3.1.18
enclosure port
physical boundary of the ~~apparatus~~ equipment, through or on which electromagnetic fields may impinge

3.1.19
far field
region where the angular distribution of the electromagnetic field is independent of distance from the antenna

Note 1 to entry: When the antenna dimensions are smaller than the wavelength, then this region is defined as $d > \lambda / 2\pi$, , where d is the distance from the antenna and λ is the wavelength of the electromagnetic field.

3.1.20
high voltage
HV
1) in a general sense, the set of voltage levels in excess of low voltage
2) in a restrictive sense, the set of upper voltage levels used in power systems for bulk transmission of electricity

[SOURCE: IEC 60050-601:1985, 601-01-27]

3.1.21
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]

3.1.22
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]

3.1.23
industrial location
location characterized by a separate power network, supplied from a high- or medium-voltage transformer, dedicated for the supply of the installation

EXAMPLE Metalworking, pulp and paper, chemical plants, car production, farm building, high-voltage (HV) areas of airports.

Note 1 to entry: Industrial locations can generally be described by the existence of an installation with one or more of the following characteristics:

- items of equipment installed and connected together and working simultaneously;
- significant amount of electrical power is generated, transmitted and/or consumed;
- frequent switching of heavy inductive or capacitive loads;
- high currents and associated magnetic fields;
- presence of industrial, high power scientific and medical (ISM) equipment (for example, welding machines).

The electromagnetic environment at an industrial location is predominantly produced by the equipment and installation present at the location. There are types of industrial locations where some of the electromagnetic phenomena appear in a more severe degree than in other installations.

Note 2 to entry: Industrial locations can be further distinguished, for example into general, process, heavy or power industrial locations.

Note 3 to entry: The connection between location and electromagnetic environment is given in 3.1.15.

[SOURCE: IEC 61000-6-2:2016, 3.7]

3.1.24
infeed converter
self-commutated electronic power converter of all technologies, topologies, voltages and sizes which is connected between the AC power supply network (lines) and usually a stiff DC side (current source or voltage source) and which can convert electric power only in one direction (from AC to DC) and limit harmonic current emissions of the converter and control the power factor to be close to one

EXAMPLE A switch mode power supply with active power factor correction (PFC) circuit.

3.1.25
islanding
process whereby a power system is split into two or more islands

Note 1 to entry: Islanding is either a deliberate emergency measure, or the result of automatic protection or control action, or the result of human error.

[SOURCE: IEC 60050-603:1986, 603-04-31]

3.1.26
ITU regions
the three geographic regions defined within the Radio Regulations are as follows:

Region 1: Europe, Africa, the Middle East west of the Persian Gulf including Iraq, the former Soviet Union and Mongolia.

Region 2: The Americas, Greenland and some of the eastern Pacific Islands.

Region 3: Most of non-former-Soviet-Union Asia, east of and including Iran, and most of Oceania.

[SOURCE: ITU Radio Regulations, Section I, 5.2 to 5.4, 2012]

3.1.27
location (EMC)
position or site marked by distinguishing electromagnetic features

3.1.28
location class
set of locations having a common property related to the types and density of electrical and electronic equipment in use, including installation conditions and external influences

Note 1 to entry: See Annex A.

3.1.29
low voltage
LV
set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V AC

[SOURCE: IEC 60050-601:1985, 601-01-26]

3.1.30
magnetic field
constituent of an electromagnetic field which is characterized by the magnetic field strength H together with the magnetic flux density B

[SOURCE: IEC 60050-121:1998, 121-11-69]

3.1.31
maximum burst power
maximum instantaneous power achieved during a burst

3.1.32
medium voltage
MV
any set of voltage levels lying between low and high voltage

Note 1 to entry: The term medium voltage is commonly used for distribution systems with voltages above 1 kV and generally applied up to and including 52 kV (see IEC 62271-1~~:2007-10~~).

[SOURCE: IEC 60050-601:1985, 601-01-28, modified – the note has been replaced by the current note.]

3.1.33
near field
region where the angular distribution of the electromagnetic field is dependent on the distance from the antenna

Note 1 to entry: When the antenna dimensions are smaller than the wavelength, then this region is defined as $d < \lambda/2\pi$, where d is the distance from the antenna and λ is the wavelength of the electromagnetic field.

3.1.34
port
particular interface of the specified ~~apparatus~~ equipment with the external electromagnetic environment

SEE: Figure 1.

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

3.1.35
power line telecommunications
PLT
use of existing in-building or network distribution power cabling as a metallic path for the distribution of data

Note 1 to entry: Power line telecommunications is also known as broadband power line (BPL) and power line communication (PLC).

3.1.36
power port
port at which a conductor or cable carrying the primary electrical power needed for the operation (functioning) of ~~an apparatus~~ equipment or associated ~~apparatus~~ equipment is connected to the ~~apparatus~~ equipment

3.1.37
residential location
location which exists as an area of land designated for the construction of domestic dwellings, and is characterized by the fact that equipment is directly connected to a low-voltage public mains network or connected to a dedicated DC source which is intended to interface between the equipment and the low-voltage mains network

EXAMPLE Examples of residential locations are houses, apartments, and farm buildings used for living.

Note 1 to entry: The function of a domestic dwelling is to provide a place for one or more people to live. A dwelling can be a single, separate building (as in a detached house) or a separate section of a larger building (as in an apartment in an apartment block).

Note 2 to entry: The connection between location and electromagnetic environment is given in 3.1.15.

[SOURCE: IEC 61000-6-1:2016, 3.8]

3.1.38
signal port
port at which a conductor or cable intended to carry signals is connected to the ~~apparatus~~ equipment

EXAMPLE Analogue inputs, outputs and control lines, data busses, antennas, communication networks, etc.

3.1.39
short interruption
sudden reduction of the voltage on all phases at a particular point of an electric supply system below a specified interruption threshold followed by its restoration after a brief interval

Note 1 to entry: Short interruptions are typically associated with switchgear operations related to the occurrence and termination of short circuits on the system or on installations connected to it.

3.1.40
TN system
power system that has one point directly earthed at the source, the exposed conductive parts of the installation being connected to that point by protective conductors

Note 1 to entry: There are three types of TN systems: TN-S, TN-C and TN-C-S.

Note 2 to entry: A description of power systems is given in IEC 60364-1.

3.1.41
unbalance factor
in a three-phase system, the degree of unbalance expressed by the ratio (in per cent) between the r.m.s. values of the negative sequence (or the zero sequence) component and the positive sequence component of voltage or current

3.1.42
voltage change
variation of the r.m.s. or peak value between two consecutive levels sustained for definite but unspecified durations

Note 1 to entry: Whether the r.m.s. or peak value is chosen depends upon the application, and which is used should be specified.

[SOURCE: IEC 60050-161:1990, 161-08-01]

3.1.43
voltage dip
sudden reduction of the voltage at a particular point of an electricity supply system below a specified dip threshold followed by its recovery after a brief interval

Note 1 to entry: Typically, a dip is associated with the occurrence and termination of a short circuit or other extreme current increase on the system or installations connected to it.

Note 2 to entry: A voltage dip is a two-dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).

3.1.44
voltage fluctuation
series of changes of r.m.s. voltage evaluated as a single value for each successive half-period between zero-crossings of the source voltage

3.1.45
wave impedance
for a sinusoidal electromagnetic wave, using complex notation, the quantity representing the electric field at a point divided by the quantity representing the magnetic field at the same point

[SOURCE: IEC 60050-705:1995, 705-03-22]

3.1.46
Smart Grid
intelligent grid
electric power system that utilizes information exchange and control technologies, distributed computing and associated sensors and actuators, for purposes such as:

- to integrate the behaviour and actions of the network users and other stakeholders,
- to efficiently deliver sustainable, economic and secure electricity supplies via an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies

[SOURCE: IEC 60050-617:2011, 617-04-13, modified – the second bullet point has been updated.]

3.2 Abbreviated terms

AC	alternating current
AIC	active infeed converter
AM	amplitude modulation
AMN	artificial mains network
ASD	adjustable speed drive (also variable speed drive)
ATSC	advanced television systems committee
AV	average

AVE	audio-visual equipment
BPL	broadband over power line
CATV	communal antenna TV
CB	citizen band
CDMA	code division multiple access
CEPT	Conférence Européenne des administrations des Postes et des Télécommunications European Conference of Postal and Telecommunications Administrations
CISPR	Comité International Spécial des Perturbations Radioélectriques International Special Committee on Radio Interference
CMA	constant modulus algorithm
CT	cordless telephony
CT-2	cordless telephone, second generation
CW	continuous wave
DC	direct current
DCCS	digital cross connect system
DCS	digital cellular system
DECT	digital enhanced cordless telecommunications
DTX	discontinuous transmission
DVB-T	digital video broadcasting – terrestrial
DVD	digital versatile disc
DVR	digital video recorder
EAS	electronics article surveillance
EDM	electro-discharge machining
EIRP	effective isotropic radiated power
EM	electromagnetic
EMC	electromagnetic compatibility
EN	~~Euro Norme,~~ European Standard
ERC	European Radiocommunications Committee
ERMES	European radio messaging system
ERP	effective radiated power
ESD	electrostatic discharge
ETSI	European Telecommunications Standardisation Institute
EU	European Union
EUT	equipment under test
FCC	Federal Communications Commission
FDD	frequency division duplex
FDMA	frequency division multiple access
FHSS	frequency hopping spread spectrum
FM	frequency modulation
FOMA	freedom of mobile multimedia access
FRS	family radio service
FSK	frequency shift keying
GMSK	Gaussian minimum shift keying

GSM	global system for mobile communications
HIPERLAN	high performance radio local area network
HEMP	high-altitude EM pulse
HPEM	high power EM
HSPA	high speed packet access
HVAC	heating, ventilation and air conditioning
IEC	International Electrotechnical Commission
iDEN	integrated dispatch enhanced network
IEEE	Institute of Electrical and Electronics Engineers
IMT	international mobile telephone
ISDB-T	integrated services digital broadcasting – terrestrial
ISM	industrial, scientific and medical
ISO	International Organization for Standardization
ITE	information technology equipment
ITU	International Telecommunications Union
JP	Japan
LAN	local area network
LCL	longitudinal conversion loss
LF	low frequency
LPRS	low power radio service
LTE	long term evolution
LTE-A	long term evolution advanced
~~Mbps~~	~~megabit per second~~
MRI	magnetic resonance imaging (also nuclear magnetic resonance)
MURS	multi-user radio service
N	neutral
NADC	North American digital cellular
OFDM	orthogonal frequency division multiplexing
PC	personal computer
PCC	point of common coupling
PDC	personal digital cellular
PDS	power drive system (also known as an adjustable speed drive or variable speed drive)
PE	indication for protective conductor
PEN	protective earth – neutral
PEP	peak envelope power
PHS	personal handy phone system
PK	peak
PLC	power line communications
PLT	power line telecommunications
PMR	public mobile radio
POCSAG	Post office code standard advisory group
PoE	ports of entry

POS	point of sale
PSD	power spectral density
PSTN	public switched telephone network
PV	photovoltaic
PVR	personal video recorder
PWM	pulse width modulated
RADAR	Radio Detection And Ranging
REIN	repetitive electrical impulse noise
RF	radio frequency
RFID	radio frequency identification
r.m.s.	root mean square
RTTT	road traffic and transport telematics
SHF	super high frequency
SHINE	single high intensity noise event
SRD	short range device
SNR	signal to noise ratio
SSB	single side band
TDD	time domain division
TDMA	time domain multiple access
TETRA	terrestrial trunked radio
THD	total harmonic distortion
TN-C	T means direct connection of one pole to earth, N means direct electrical connection of the equipment to the earthed point of the power distribution system (in AC systems, the earthed point of the power distribution system is normally the neutral point or, if a neutral point is not available, a phase conductor); C means the neutral and protective functions are combined in a single conductor.
TN-S	T means direct connection of one pole to earth, N means direct electrical connection of the equipment to the earthed point of the power distribution system (in AC systems, the earthed point of the power distribution system is normally the neutral point or, if a neutral point is not available, a phase conductor), S means the neutral and protective functions are separate conductors.
TV	television
UHF	ultra high frequency
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System
UPCS	Unlicensed Personal Communications Services
UPS	uninterruptable power system
US	United States of America
UTP	unscreened twisted pair
UV	ultra violet
UWB	ultra wide band
VCR	video cassette recorder

VDU	video display unit
VHF	very high frequency
WMTS	wireless medical telemetry service
WLAN	wireless local area network

4 User's guide for this document

4.1 Approach

Classification of the electromagnetic environment is based on the classification or a description of the electromagnetic phenomena prevailing at typical locations, not on existing test specifications. However, given a choice among equal possibilities, harmonization with existing test specifications (if appropriate) will simplify the situation and promote easier acceptance of the recommendations. The definition of electromagnetic environment in 3.1.15 refers to "electromagnetic phenomena". The term "disturbance degree" (3.1.9) is used in this document to quantify the phenomena contributing to the electromagnetic environment and it is independent of any consideration of test levels. The term "severity level" is not used in this document to describe the environment, as it is reserved for specifying immunity test levels in other IEC publications.

Thus, the concept and term of electromagnetic phenomenon is the starting point for defining the environment and selecting disturbance degrees in a classification document. Clauses 5, 6 and 7 of this document are the first step of the process. Three basic categories of phenomena have been identified: low-frequency phenomena, high-frequency phenomena and electrostatic discharge. In the first stage, attributes of the phenomena (amplitudes, waveforms, source impedance, frequency of occurrence, etc.) are defined generically, and the expected range of disturbance degrees established. Then, in the second stage, one single value from that range has been identified as most representative value for each phenomenon at a specific class of location and set forth as the compatibility level for that location class.

The process is illustrated in Figure 1, showing how two sets of tables are used: a set of input tables that are phenomena-oriented and establish a range of disturbance degrees for a given phenomenon, and a set of output tables that are location-oriented and propose a table for each class, with one value of compatibility level for each of the phenomena identified in the set of input tables.

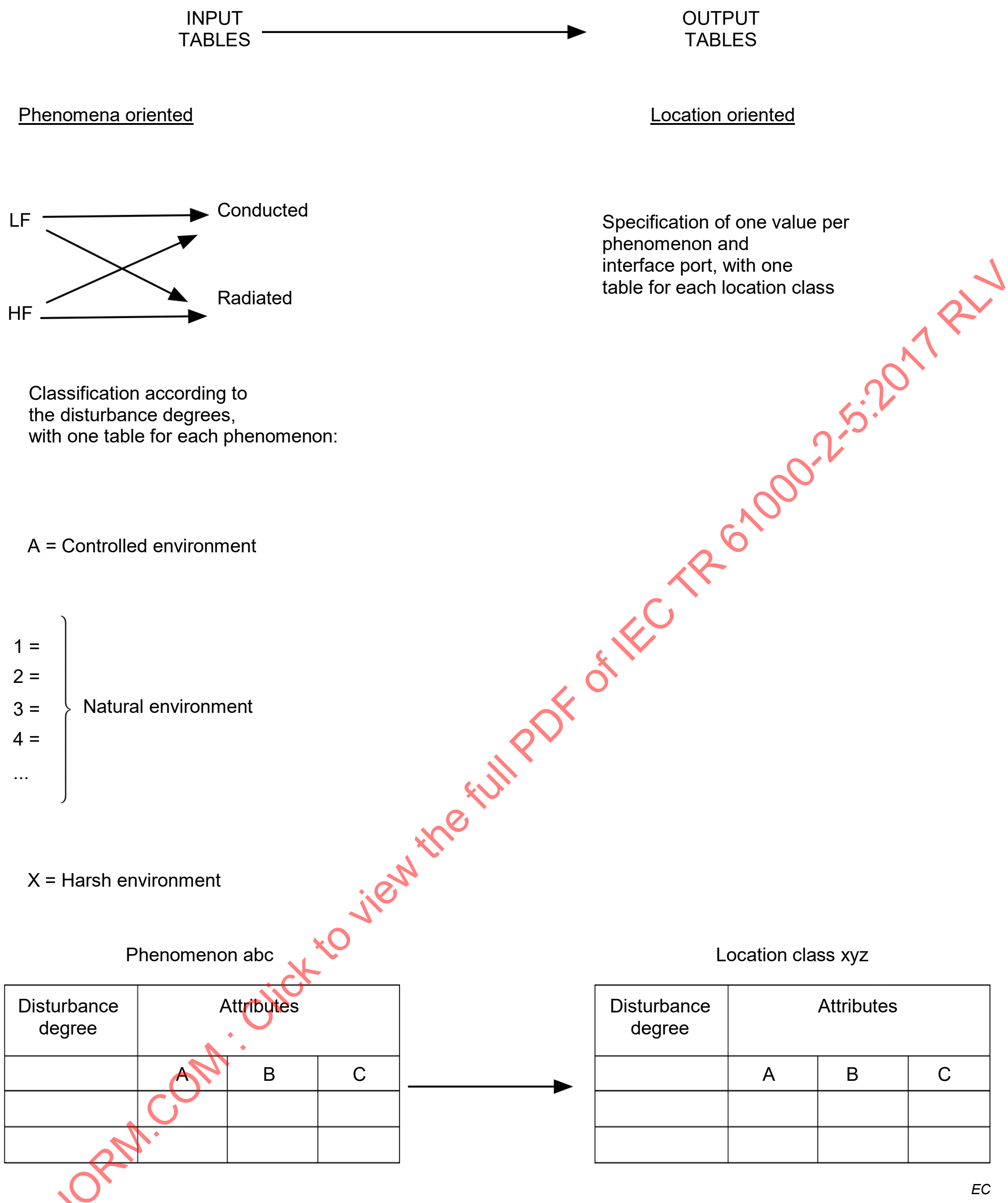


Figure 1 – Schematic of the two-step approach used for classification with phenomenon-oriented input tables and location-oriented output tables

Electromagnetic disturbances impinge on equipment by radiation or by conduction. A useful concept is to consider a set of ports, as shown in Figure 2, through which the disturbances enter (or exit) the equipment under consideration. The nature and degree of disturbing phenomena depends on the type of port, so that the tables in this document will take this into consideration. Electromagnetic radiated disturbances impinge on equipment from distant or close sources, hence the propagation and coupling can be governed by far-field or by near-field characteristics. Radiated disturbances that couple into the conductors connected to the equipment, but outside the equipment enclosure, become conducted disturbances. These are addressed under the various phenomena listed under conducted disturbances. The enclosure port shown in Figure 2 concerns only the radiated disturbances that enter the equipment through its envelope (either an actual barrier such as a shield, metallic cabinet, etc., or a physical barrier with no electromagnetic impact, such as a plastic housing).

The equipment shown in Figure 2 is a finished product with an intrinsic function for final use.

– The enclosure port is the physical boundary of the ~~apparatus~~ equipment, which electromagnetic fields may radiate through or impinge upon. The equipment case is normally considered the enclosure port.
– The signal port is the point where a cable carrying signals to or from the equipment or controlling the equipment can be connected. Examples are input/output (I/O) data/control lines, telecom lines, antenna cables, wired network lines, etc.
– The earth port is the point where a cable ~~connection other than a signal or power port,~~ intended for connection to earth for functional or safety purposes can be connected.
– The power port is the point where a conductor or cable is connected to the equipment carrying the electrical power (AC or DC) needed for operation. The power port can be both input or output power port.

The significance of differentiating ports for conducted disturbances reflects the different types of phenomena that can occur in power systems versus communication systems, as well as the importance of earthing practices for each of the systems, as earth often serves as a reference for the equipment. For the purposes of this classification, the signal and control ports are considered similar and are therefore combined into the signal port. Users need to recognize that the values shown correspond to disturbances measured between the conductors of the specific systems, in what is described as a differential mode, a common mode or an asymmetrical mode.

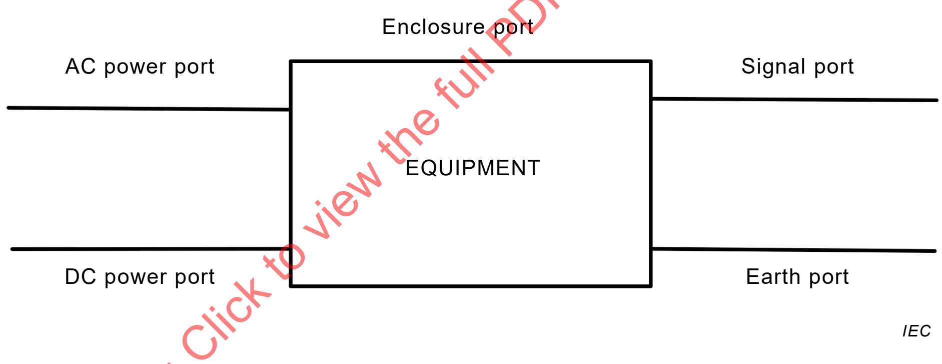


Figure 2 – Ports of entry (POEs) of electromagnetic disturbances into equipment

The final classification of environments into location classes and corresponding compatibility levels is discussed in Clause 8, with specific examples of location classes given in the tables of Annex A. In that respect three location classes have been identified in this document (see Figure 7). The attributes of these location classes are based on the significant electromagnetic characteristics of a location, rather than geographical or structural aspects. The location labels of the final classification imply specific definition of significant electromagnetic attributes. Classes of locations other than those listed in Annex A may be identified and added to the set as the need arises.

It should be noted that this classification is based on environment data collected up to ~~2010~~ 2015. The disturbance degrees shown in Annex A are offered as examples of compatibility levels for the guidance of product committees, not as immunity requirements. Those values are affected by uncertainties, and they may not cover extreme environments.

4.2 Rationale for classification system

The purpose of a classification system is to identify a limited set of parameters and associated values which may be chosen when identifying performance requirements. The purpose of such a system is primarily economic, in that it limits the number of variations in the number of types of equipment which a manufacturer may produce. It also identifies the need (if any) for appropriate interfaces.

The classification system proposed is rather exhaustive, and shows numerous electromagnetic phenomena. It does not necessarily mean that the immunity of a given item shall be tested against all these phenomena, but that a limited set of them may be chosen according to the environment of concern and inherent characteristics of the item.

4.3 Electromagnetic environment phenomena

The electromagnetic environment in which electrical and electronic items are expected to operate without interference is very complex. For the purpose of this classification, three categories of electromagnetic environment phenomena have been defined to describe all disturbances:

– electrostatic discharge (ESD) phenomena (conducted and radiated);
– low-frequency phenomena (conducted and radiated, from any source except ESD);
– high-frequency phenomena (conducted and radiated, from any source except ESD).

This distinction is necessary in order to recognize that electromagnetic disturbances occur in a particular medium. Formally, when dealing with the electromagnetic environment, the wavelength λ of the considered disturbance is the gauge for “long or large” and for “short or small”. An item is small or a line is short if the wavelength is much greater than its dimensions. Consequently, in that situation the frequency is low, as the frequency is inversely proportional to wavelength. An item is large or a line is long if the wavelength is much smaller than its dimensions. However, in the context of the present document and in accordance with the IEC EMC approach, the term low frequency applies to frequencies up to and including 9 kHz; the term high frequency applies to frequencies above 9 kHz.

Electromagnetic radiation in different locations may be a result of intentional or unintentional radiators and may include electromagnetic fields on frequencies from 0 Hz (static fields) to 400 GHz. Electromagnetic fields can be radiated from distant or close sources, hence the propagation and coupling can be governed by far-field or by near-field characteristics. The resulting field strength at a location is typically controlled by the radiated power, the distance from the radiator and coupling effectiveness. The frequency is also an important factor in order to describe electromagnetic fields at a location.

Radiated disturbances occur in the medium surrounding the equipment, while conducted disturbances occur in various metallic media. The concept of ports as shown in Figure 2, through which disturbances have an impact on the item, allows a distinction among the following various media:

1) enclosure;
2) AC power mains;
3) DC power mains;
4) signal lines;
5) interface between items and earth or reference.

The source, the coupling and the propagation characteristics depend on the type of medium. The final tables of Annex A show the compatibility levels for various location classes, and are structured along this concept of corresponding ports.

4.4 Relationship of disturbance levels to CISPR limits

In general compatibility levels are used as reference for coordination in the setting of emission limits and immunity levels (see also IEC TR 61000-1-1). The disturbance levels given in this document should be used to determine the compatibility levels.

Emissions from equipment (or from a system made of items of equipment) should be set in such a way that together with appropriate immunity levels of other items of equipment electromagnetic compatibility is achieved. The easiest approach would be to set the emission limits lower than the immunity levels, placing a margin between limits and levels which takes into account, for example, tolerances in the hardware properties of the items of equipment, potential coupling mechanisms between items of equipment and statistical considerations.

Hence, setting emission limits in this way predominantly aims at the achievement of electromagnetic compatibility. Such types of emission limits are not related to CISPR emission limits as for the specification of CISPR limits a different approach is applied.

CISPR limits are developed for protection of radio communications. They take into account aspects such as field strength signals needed for radio reception or typical protection distances between radio receivers and potential interference sources (typically 10 m or 30 m). They do not take into account the situation in very close proximity of disturbance sources (as this is not a typical situation for reliable radio reception) or immunity issues as the CISPR emission limits are normally far below (several magnitudes) typical immunity levels. In this respect, emission limits derived from the disturbance levels of this document and CISPR limits are not always correlated with each other. Consequently, the disturbance levels of this document are in most cases not appropriate to derive CISPR limits.

NOTE More detailed information about determining CISPR emission limits are given in CISPR TR 16-4-4.

4.5 Simplification of the electromagnetic environment database

It is neither possible nor absolutely necessary to describe completely an electromagnetic environment. Consequently, any description is limited to certain properties of this environment. The first step of a description should be the selection of appropriate electromagnetic properties corresponding to the various phenomena that can create electromagnetic disturbances. Table 1 lists these phenomena. In this document, the boundary between low frequency and high frequency is generally understood as being 9 kHz; however, when addressing a type of disturbance prevailing in one frequency range with a small overlap into the other range, the boundary might be slightly shifted to keep the phenomenon within one descriptive range.

An appropriate selection is only valid if its purpose is also specified. Considering the many possible coupling mechanisms between an item and its electromagnetic environment, it becomes apparent that, in order to accurately assess the necessary level of immunity for any item, more information than is available about the environment would be needed. Accuracy of electromagnetic environment descriptions is necessarily limited, as follows:

– some aspects of the environment are disregarded because the information is not available;
– some aspects of the environment are disregarded because a classification system taking them into account would become too complex;
– a statistical approach may be necessary, in order to consider only those events for which the occurrence is likely.

The first two limitations are embedded in the selection of the disturbance types, while the statistical aspect appears in the definition of environment classes and the selection of a single value for compatibility levels, rather than a range of values.

Available databases at the time of elaboration of this document indicate the wide variety of conducted and radiated disturbances that can be expected to occur in the diverse environments encountered in the use of equipment. Evaluation by laboratory tests of the ability of equipment to withstand these environments, or of the effectiveness of mitigation methods, can be facilitated by a synthesis of the database. This synthesis leads to selecting a few representative disturbance phenomena that will make tests uniform, meaningful and replicable.

Table 1 – Principal phenomena causing electromagnetic disturbances

Phenomena		Table	Subclause
LF-conducted			
Power supply networks	Harmonics/inter-harmonics	2	5.1.1
	Voltage fluctuations	3	5.1.2.1 a)
	Voltage dips	None	5.1.2.1 b)
	Voltage interruptions	None	5.1.2.1 c)
	Voltage unbalance	4	5.1.2.1 d)
	Voltage frequency variations	5	5.1.2.2
Power supply networks	Common mode voltages	6	5.1.3
	Signalling voltage 0,1 kHz to 3 kHz	7	5.1.4
	Induced LF	8	5.1.6
	DC in AC networks	None	5.1.7
Signal and control cables	Induced LF (normal conditions)	8	5.1.6
	Induced LF (fault conditions)	8	5.1.6
LF magnetic field	DC	9	5.2.1
	Railway	9	5.2.1
	Power system	9	5.2.1
	Power system harmonics (n = harmonics)	9	5.2.1
	not power system related	9	5.2.1
LF electric field	DC lines	10	5.2.2
	Railway (~~16 2/3~~ 16,7 Hz)	10	5.2.2
	Power system (50 Hz/ 60 Hz)	10	5.2.2
HF phenomena			
Signalling voltage/PLT	3 kHz to 95 kHz	7	5.1.4
	95 kHz to 148,5 kHz	7	5.1.4
	148,5 kHz to 500 kHz	7	5.1.4
Direct-conducted CW/PLT (intentional)	~~PLT (~2 MHz to 30 MHz)~~ 1,606 5 MHz to 87,5 MHz	None	6.1.2
Direct-conducted CW (unintentional)	9 kHz to 150 kHz	11	6.1.2.4
HF-conducted induced CW	10 kHz to 150 kHz	12	6.1.3
	0,15 kHz to 150 MHz	12	6.1.3

Unidirectional transients	Nanoseconds	13	6.1.4
	Microseconds, close	13	6.1.4
	Microseconds, distant	13	6.1.4
	Milliseconds	13	6.1.4
HF-conducted oscillatory transients	High frequency	14	6.1.4
	Medium frequency	14	6.1.4
	Low frequency	14	6.1.4
HF radiated			
Radiated CW	ISM Group 2	16	6.2.2
Radiated modulated	Mobile units GSM DCS1800 DECT	21, 22	6.2.3.2
	Base stations	23, 24	6.2.3.2
	Medical and biological telemetry items	25	6.2.3.2
	Digital television broadcast	26, 27, 28	6.2.3.2
	Unlicensed radio services	29, 30	6.2.3.2
	Paging services (base station)	32	6.2.3.2
	RFID + railway transponder	39, 40	6.2.3.3
	Other RF items	19, 20, 33, 34, 35, 36, 37, 38	6.2.3.2
	Amateur radio stations	17	6.2.3.1
		31	6.2.3.2
	CB	18	6.2.3.1
Radiated pulsed	Radiated transients	41	6.2.4
	RADAR	42	6.2.4
ESD	Slow	43 / 44	7.2 / 7.3
	Fast	43 / 44	7.2 / 7.3
High altitude electromagnetic pulse (HEMP)	Not considered in this document; for further information see IEC 61000-2-9		
High power electromagnetic pulse (HPEM)	Not considered in this document; for further information see IEC 61000-2-13		

To assist equipment designers and users in making appropriate choices in defining immunity test levels, the classification shows, for each phenomenon, only one compatibility level per class of location. The characterization of each phenomenon is presented in tabular form, from which a selection can be made. This approach gives a common base of reference for specifying immunity requirements for an item of equipment expected to be installed at various locations, and yet provides the appropriate degree of compromise between a conservative overdesign and a cost-conscious reduction of margins. The specification of these requirements for specific equipment remains the field of product standards and, therefore, cannot be addressed in the present document.

For a given equipment, the surrounding environment in which it is required to operate results from the presence and nature of disturbance sources, as well as from the installation conditions adopted. Typical installation practices take into consideration the mitigation which can be obtained by separation, shielding and suppression. Therefore, it is important to take into consideration the effect of these practices when suggesting disturbance degrees in specific locations where various installation practices are generally applied. This document assigns a representative degree for the various types of installations likely to be found at those locations.

The listing of disturbance degrees includes an "A" degree, for an environment where some mitigation or control might be necessary to satisfy specific requirements, and an "X" degree recognizing that in some situations exceptional conditions could prevail that need specific recognition. The "A" degree corresponds to a situation where the environment is somewhat controlled by the nature of the building, or installation practices inherent to a particular location class. The "X" degree corresponds to a degree of disturbance higher than is generally encountered.

As with any classification scheme, its value lies in its generality. This classification recognizes that there could be exceptional requirements associated with any specified location. The consequences of such an occurrence shall be taken into account in designing equipment for operation in a particular classification category. For example, a particular type of switching transient can occur infrequently in some location classes. Whether the equipment should be designed to be "immune" to this particular disturbance depends upon whether its effects are temporary (for instance, a reduction of reception quality that might be acceptable although undesirable), or permanent and unacceptable (equipment damage or malfunction with unacceptable consequences).

If no special performance requirement is expected at a given location, which is the general case, the procedure is reduced to:

- selecting the appropriate location class from those defined in Clause 8 and Annex A;
- selecting the required immunity in accordance with the principles stated in Clause 9.

The purpose of this document is not to specify immunity, but to allow product committees to make a selection on a rational and informed basis, without specifying equipment immunity. Data shown in the Table 2 to Table 14 and Table 16 to Table 44 refer to well-known electromagnetic environment conditions, such as low-frequency phenomena or, in other cases, only proposed as representative levels for classification.

5 Low-frequency electromagnetic phenomena

5.1 Conducted low-frequency phenomena

5.1.1 Harmonics of the fundamental power frequency

Harmonic voltages of the fundamental power frequency exist on power supply networks. The source is harmonic currents of the fundamental power frequency that are injected into the power supply network by attached non-linear loads, where they are converted into voltages by the network impedance.

The number of non-linear loads that are utilised in residential, commercial and industrial locations has increased significantly in recent years. There are two types of non-linear loads:

– The very large number of small capacity loads (i.e. each consuming less than 1 kW), mostly single-phase loads, that are found in the low-voltage power distribution network. Such loads typically have rectifier input and include items such as household appliances, AVE, ITE, etc.

– The small number of large capacity loads (i.e. each consuming more than 1 kW) that may be found in low-voltage, medium-voltage and high-voltage power distribution networks. Such loads include industrial power drive systems and other manufacturing devices.

For low-voltage public supply networks, the main sources of harmonic voltages are the very large number of small capacity loads. IEC 61000-1-4 reviews the sources and effects of the emissions of power frequency conducted harmonic currents in the low-voltage networks.

For low-voltage, medium-voltage and high-voltage industrial power supply networks, the main sources of harmonic voltages are the small number of large capacity loads.

Harmonics from residential, commercial and industrial areas aggregate to disturb the voltage of the supply network. Table 2 shows:

– the disturbance levels for the individual voltage harmonic components;
– the THD:

$$THD = \sqrt{\sum_{n=2}^{40} \left(\frac{U_n}{U_1} \right)^2} \tag{1}$$

where

U_n is the amplitude of the n^{th} harmonic of the fundamental power frequency;

U_1 is the amplitude of the fundamental power frequency.

NOTE 1 The definition of the THD recognises the fact that not all harmonic components will reach their peak amplitude simultaneously.

NOTE 2 Harmonics up to and including the 40^{th} harmonic are considered, in conformity with IEC 61000-3-2.

Table 2 – Disturbance degrees and levels for harmonic voltages in power supply networks (in percentage to fundamental voltage, U_n/U_1)

Harmonic order	THD	Odd (non-multiple of 3)								Odd and multiple of 3					Even			
	THD	5	7	11	13	17	19	23-25	>25	3	9	15	21	>21	2	4	6-10	>10
Basic document **Disturbance degree**	IEC 61000-2-2, IEC 61000-2-4 and IEC 61000-2-12																	
A (Controlled)	Case-by-case according to the equipment requirements																	
1	5	3	3	3	3	2	a	a	a	3	1,5	0,3	0,2	0,2	2	1	0,5	c
2	8	6	5	3,5	3	2	a	a	a	5	1,5	0,4	0,2	0,2	2	1	0,5	c
3	10	8	7	5	4,5	4	b	b	b	6	2,5	2	1,75	1	3	1,5	1	1
X (harsh)	Case-by-case according to the situation																	

NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4.

NOTE 2 Class 1 applies to protected supply networks and has compatibility levels lower than those of public supply networks. It relates to the use of equipment that is very sensitive to disturbances in the power supply, for instance the instrumentation of technological laboratories, some automation and protection equipment, some computers, etc.

NOTE 3 Class 2 applies to low-voltage public supply networks (see IEC 61000-2-2). It ~~may~~ can also apply to commercial and light industrial environments (small- and medium-size industrial plants, commercial buildings).

NOTE 4 Class 3 applies to industrial environments. It has higher compatibility levels than those of Class 2 for some disturbance phenomena. For instance, this class ~~should~~ would be considered when any of the following conditions are met:

- a major part of the load is fed through power converters;
- welding machines are present;
- large motors are frequently started;
- loads vary rapidly.

NOTE 5 Class X applies to an arbitrarily defined environment, for example, strongly disturbed industrial power supply networks (steel plants, power stations, etc.).

The above levels correspond to those values that are not exceeded by 95 % of the 10 min mean r.m.s. values during each period of one week under normal operating conditions (taken from EN 50160).

a = 2,27 × (17/n) – 0,27 (where n is the order of the harmonic component)

b = 4,5 × (17/n) – 0,5 (where n is the order of the harmonic component)

c = 0,25 × (10/n) + 0,25 (where n is the order of the harmonic component)

5.1.2 Power supply network voltage amplitude and frequency changes

5.1.2.1 Amplitude change

The voltage amplitude of the 50/60 Hz power network can be subject to various disturbances.

a) Continuous or randomly repeated and relatively rapid fluctuations within the normal operating range occur at a frequency ranging from 25 times per second to one time per minute. The most disturbing effect of such fluctuations is a flickering of lighting levels (mainly low-voltage incandescent lamps), causing physiological discomfort. Sources are generally industrial loads such as arc furnaces (HV network), welding machines (LV network) and switching of large loads or capacitor banks. Table 3 lists disturbance levels for voltage fluctuations within normal operating range.

Table 3 – Disturbance degrees and levels for voltage changes within normal operating range (in percentage of nominal voltage, $\Delta U/U_n$)

Disturbance degrees	Basic standard
	IEC 61000-2-4
	Disturbance levels
A (controlled)	Case-by-case according to the equipment requirements
1	±8 %
2	±10 %
3	–15 % to +10 %
X (harsh)	Case-by-case according to the situation

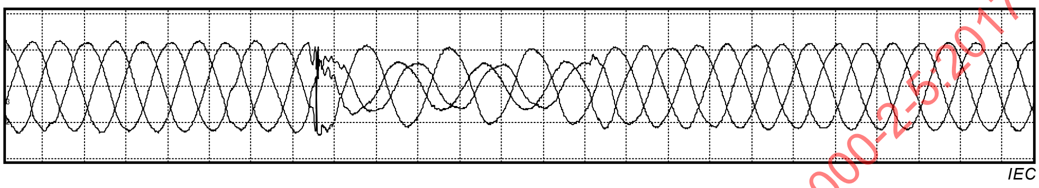
NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4.

NOTE 2 A range of −15 % to +10 % ~~may~~ can occur for a duration shorter than 60 s. For longer duration, a range of −10 % to +10 % applies.

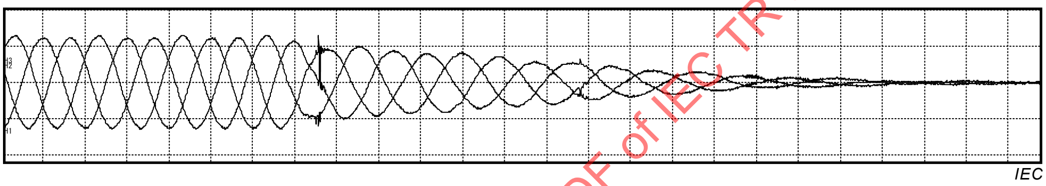
b) Voltage dips last in most cases for less than 1 s. In areas supplied by overhead lines, the number of voltage dips can reach several hundreds per year, depending on the number of lightning strokes and other meteorological conditions in the area. In areas supplied by underground power cables an individual user of electricity connected at LV may be subject to voltage dips occurring at a rate that extends from around ten per year to about a hundred per year, depending on local conditions.

c) Short supply interruptions with durations ranging up to 180 s also occur. Most of them are restored within 60 s. Interruptions lasting more than 180 s are no longer considered an EMC issue, but a blackout.

d) Voltage unbalance can be caused by asymmetrical loads or large single-phase loads such as traction systems or single-phase furnaces. Table 4 shows the disturbance degrees.



a) – Voltage dip



b) – Short supply interruption

Figure 3 – Typical voltage waveforms for dip and interruption (10 ms/horizontal division)

NOTE 1 Voltage dips and short interruptions have various origins:

– short circuits in LV networks cleared by fuse operation (a few milliseconds);

– faults on MV and HV overhead lines or other equipment, followed or not followed by automatic reclosure (almost 70 ms to 1 000 ms);

– switching of large loads, especially motors and capacitor banks.

Examples of voltage waveforms for voltage dip and short supply interruption are shown in Figure 3.

NOTE 2 The disturbance degrees and compatibility levels for these phenomena, i.e. voltage dips and short supply interruptions, are not yet available. Further information and suitable immunity levels on these phenomena are given in IEC 61000-2-2, IEC 61000-2-4, IEC TR 61000-2-8, IEC 61000-4-11 and IEC 61000-4-34.

Table 4 – Disturbance degrees and levels for voltage unbalance (in percentage of U_{neg}/U_{pos})

Disturbance degrees	Basic standard
	IEC 61000-2-2, IEC 61000-2-4 and IEC 61000-2-12
	Disturbance levels
A (controlled)	Case-by-case according to the equipment requirements
1	2 %
2	2 %
3	3 %
X (harsh)	Case-by-case according to the situation

NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4.

NOTE 2 Levels are indicated for the ratio of the negative phase sequence component to the positive one.

5.1.2.2 Frequency change

The fundamental frequency of a power supply network is generally very stable, varying by no more than 0,2 %. However, during network disturbances, the fundamental frequency of the power network can vary by up to 4 % (see Table 5).

Table 5 – Disturbance degrees and levels for power frequency variation

Disturbance degrees	**Basic standard**
	IEC 61000-2-2, IEC 61000-2-4 and IEC 61000-2-12
	Disturbance levels
A (controlled)	Case-by-case according to the equipment requirements
1	±1 Hz
2	±1 Hz
3	±1 Hz
X (harsh)	Case-by-case according to the situation

NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4.

NOTE 2 For isolated power networks, ±2 Hz applies.

5.1.3 Power supply network common mode voltages

In power supply networks, both phase voltages and phase-to-phase voltages should be identified. Phase voltages correspond to the phase conductor voltages against the ground concerned. Phase-to-phase voltages can be regarded as normal mode (or differential mode) voltages, while the common mode voltage is given by the average of the phase voltages. For polyphase systems the common mode voltage equals the neutral line voltage. Since the neutral line is usually grounded, relative current flows through the neutral conductor when the common mode voltage occurs.

A common mode voltage should be stationary in power supply networks. If high-frequency components are contained in it, insulation breakdown, increase of grounding current or noisy electromagnetic radiation may occur. An electric shock could also occur in the worst case.

Semiconductor power converters are widely adopted in industrial machines and distributed generators, such as PDS, PV generation, etc. In many cases, these devices are connected to the power supply network directly, without transformers. This arrangement may change the common mode voltage of the input/output lines rapidly with the switching frequency. In the case of PWM converters, the frequency of the common mode voltage change can range from several hundred Hertz to over 100 kHz.

Figure 4 shows a typical configuration of the semiconductor converter in a PDS: a 3-phase AC network voltage is rectified to DC voltage by a diode-rectifier. For the purpose of simplifying the explanation, the neutral point of the AC network is assumed to be grounded. The DC voltage is further converted to a 3-phase AC voltage with adjustable frequency and amplitude by a PWM inverter. The output voltage feeds an induction or synchronous motor.

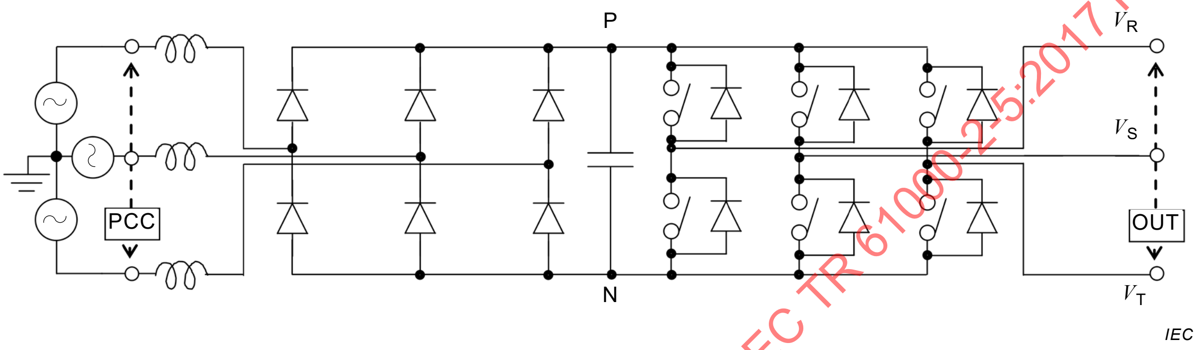
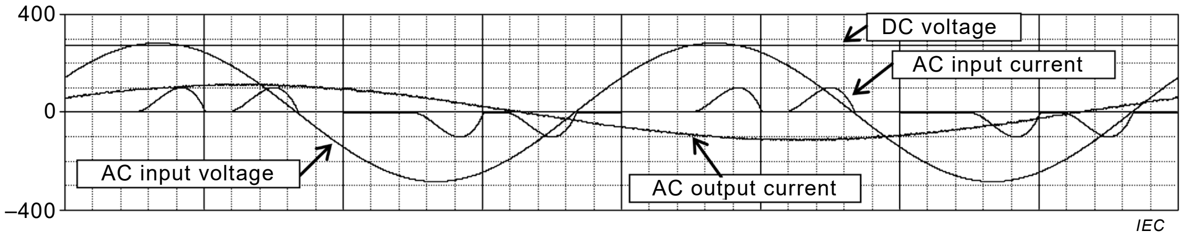


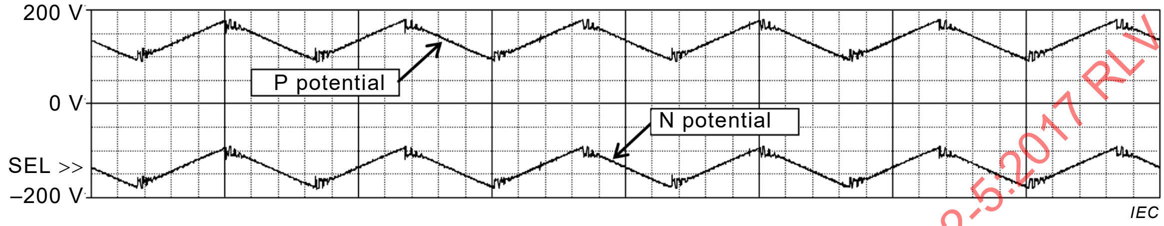
Figure 4 – Typical configuration of the converter in a PDS

Figure 5 depicts an example of the voltage and current waveforms at each position in a PDS. The AC network frequency is 50 Hz. The PDS output frequency is 25 Hz. A representative AC input phase-to-phase voltage, a representative AC input phase current, the DC voltage and a representative AC output phase current are shown in of Figure 5a). The AC input phase current includes large harmonic components, whereas the AC output current is controlled to be almost sinusoidal. Figure 5b) indicates both the DC positive pole (P) voltage potential from the ground and that of the negative pole (N). The DC line potential from the ground fluctuates at 150 Hz (50 × 3). The DC differential voltage fluctuates at 300 Hz (50 × 6), though this fluctuation is very small. Figure 5c) displays the common mode (neutral) voltage of the converter output, which contains multiples of the PWM carrier frequency (5 kHz) components. The envelope of the common mode voltage follows the DC P and N potential voltages. It is the significant feature of PDS that the output common mode voltage is pulsating at the PWM carrier frequency although the output current gets almost sinusoidal.

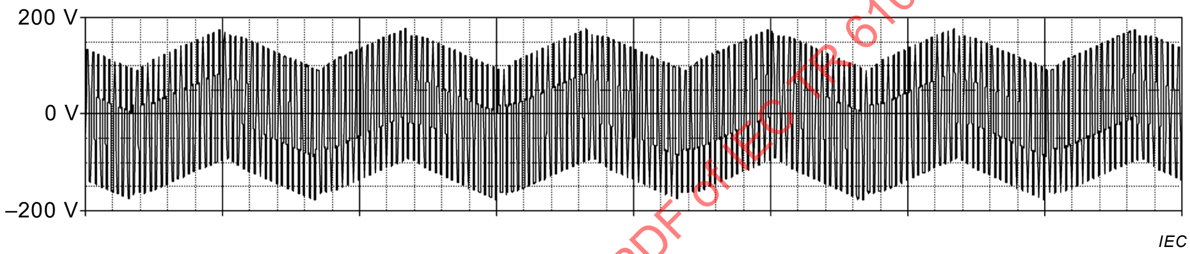
One example of a measured PDS common mode voltage is introduced in Figure 6. The Figure was taken for between 150 kHz and 30 MHz through an AMN. The motor capacity was 3,7 kW and the switching frequency of the PDS was 14,5 kHz. Since a peak measuring receiver was used instead of a quasi-peak measuring receiver, the detected value would be several dB higher. It is found that about 100 dB(μV) conducted common mode disturbance voltage is generated.



a) – Waveforms of input and output currents, and link voltage

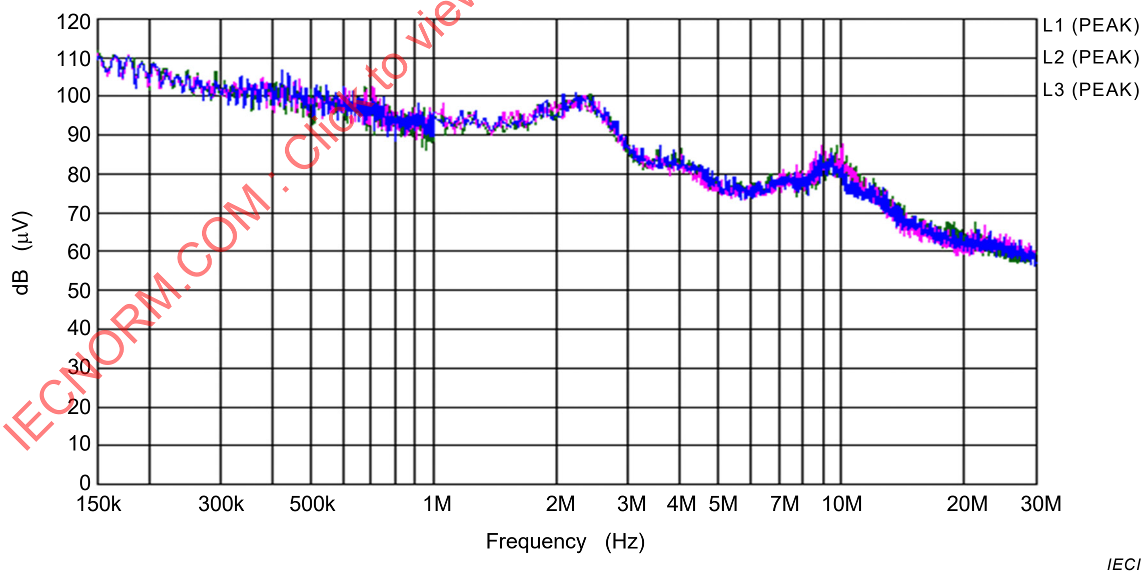


b) – DC link potential fluctuation



c) – Common mode voltage of the converter output

Figure 5 – Voltage and current waveforms of each PDS portion (1 ms/horizontal division)



NOTE The common mode voltage produced by a PDS causes various interferences:

1) Rise of bearing current resulting in lifetime reduction.

2) Surge voltage resulting in insulation deterioration of motor windings.

3) Generation of stationary grounding current.

4) Induced radio interference.

Figure 6 – Measured common mode voltage at the input terminal of a converter

Disturbance degrees and levels for common mode voltages are given in Table 6.

Table 6 – Disturbance degrees and levels for common mode voltages

Disturbance degrees	Basic standard
	IEC 61000-4-16
	Disturbance levels
1	1 V
2	3 V
3	10 V
4	30 V
X (harsh)	Case-by case according to the situation
NOTE 1 A more detailed description of the environments in terms of installation conditions or equipment under operation is given in IEC 61000-4-16:2015, Annex B. NOTE 2 Values in $V_{r.m.s.}$	

5.1.4 Signalling voltages in power supply networks

Power supply networks are designed for the transmission of energy, but they can also be used for the transmission of information by mains signalling systems. The relevant standardization documents consider three types of systems:

– ripple control systems that are used by electrical utilities in public supply networks, in the range of 100 Hz to 3 kHz, generally below 500 Hz, with signals up to 5 % of U_n under normal circumstances and up to 9 % of U_n in cases of resonance. These systems are used in some countries in Europe and elsewhere;

– power-line carrier systems used by electrical utilities in public supply networks, in the range 3 kHz to 95 kHz, with allowed signal levels up to 5 % of U_n. These signals are strongly attenuated in the network (> 40 dB). These systems are used mainly in Europe, in the US and are developing elsewhere;

– signalling systems for end-user premises (residential or industrial) in the range of 95 kHz to 148,5 kHz in Europe (ITU region 1), with allowed signal levels up to 0,6 % U_n or 5 % U_n, respectively. In the US and Japan the upper frequency is 500 kHz, with allowed signal levels between 2 mV and 0,6 mV.

Disturbance degrees and levels for signalling voltages in power systems are given in Table 7.

Table 7 – Disturbance degrees and levels for signalling voltages in ~~power~~ low and medium-voltage systems (in per cent of nominal voltage U_n)

Disturbance degrees	**Frequency range** in kHz			
	0,1 to 3	3 to 95	95 to 148,5	148,5 to 500
	Disturbance levels			
A (controlled) [a]	Case-by-case according to the equipment requirements			
1 [b]	0,1 kHz to 0,5 kHz: ~~5~~ 9 % U_n [d] ~~0,5 kHz to 3 kHz: 5 % U_n to 1,3 % U_n~~ 0,5 kHz to 0,95 kHz: 9 % U_n to 5 % U_n [d] 0,95 kHz to 3 kHz: 5 % U_n [d]	3 kHz to 9,5 kHz: 5 % U_n [d] 9,5 kHz to 95 kHz: 5 % U_n to 1,3 % U_n [d]	General: 0,6 % U_n Industrial areas: 5 % U_n	2 to 0,6 (mV, not %)
X (harsh) [c]	Case-by-case according to the situation.			

NOTE 1 Degree A: residual signals might exist, coupled from adjacent systems where intentional signals might be present. For this degree, in contrast with other tables, degree A is not a controlled environment. Furthermore, some types of installations might offer some degree of protection against this disturbance phenomenon. In case of disturbing over-spill from adjacent networks, it might be necessary to install blocking or absorbing circuits.

NOTE 2 Degree 1: for the range 0,1 kHz to 3 kHz, the values correspond to normal injection levels in actual installations. For the other ranges, the values indicate the maximum allowed injection level measured on a reference impedance. These values are only applied in ITU region 1, and other values might be used in ITU region 2 or 3.

NOTE 3 Degree X: normally the signals are more or less attenuated in the network. However, in certain cases of resonance the signals ~~may~~ can be enhanced. ~~In the range 0,1 kHz to 3 kHz, a maximum of 9 % U_n is allowed.~~

[a] Network without signalling.

[b] Emission level, near to the transmitter.

[c] Special cases (resonances).

[d] ~~No data available.~~ EN 50160:2010 (Figure 1 and Figure 2) gives information on possible levels of signaling voltages which may be present in public power supply networks. The values are valid for low-voltage and medium-voltage power supply networks.

5.1.5 Islanding supply networks

The term islanding describes the process whereby a power system is split into two or more islands. Islanding mainly occurs when either a deliberate emergency measure or an automatic protection/control action is taken. If the scale of an islanding network is relatively small, its power frequency fluctuation and voltage fluctuation can be larger than usual.

To protect installations like hospitals, server farms, shopping centres and warehouses during ‘black outs’ or ‘brown outs’, most of these installations have an independent backup system for their power supply. This is done by either a backup generator or a UPS. When the backup system is in operation, the fluctuation in both the power frequency and the voltage amplitude can be larger than the normal conditions specified in 5.1.2.

Islanding is not limited to the situations mentioned above. For some environments the situation of a relatively small power supply network can be the normal situation. Examples of such environments include:

– a small island, town or house that is physically isolated from a public distribution network and hence has a separate, independent power supply network that is driven by diesel generator, photovoltaic power system or other power source;

– a vessel (ship or aircraft) or off-shore installation.

In these situations the normal power quality conditions may not exist. It is recommended for small power networks that a case-by-case assessment be performed to determine the various aspects of power quality.

5.1.6 Induced low-frequency voltages

Low-frequency currents in cables might (according to actual currents, physical layout, cable type and other parameters) induce low-frequency common mode voltages into adjacent cables. The coupling impedance varies according to the proximity of the cables and the effective parallel length.

Table 8 describes induced common mode voltages. Differential mode voltages may also occur and are strongly dependent on the type of cable, termination and earthing arrangement.

Table 8 – Disturbance degrees and levels for low-frequency, common mode induced voltages in signal and control cables

Disturbance degrees	Phenomena (sources) and basic standard				
	Power distribution and mains cables carrying network frequency and harmonics under normal operating conditions IEC 61000-4-16				Fault condition in power system [a] IEC 61000-4-16
	Disturbance levels				
	~~50 Hz to 1 kHz~~ ~~[b]~~ 15 Hz to 150 Hz [c]	~~1 kHz to 20 kHz~~ 150 Hz to 1,5 kHz	1,5 kHz to 15 kHz [d]	15 kHz to 150 kHz	50 Hz to 1 kHz
A (controlled)	Case-by-case according to the equipment requirements				
1	~~0,05 – 1~~ 1 to 0,1	~~0,05~~ 0,1	0,1 to 1	1	100
2	~~0,15 – 3~~ 3 to 0,3	~~0,15~~ 0,3	0,3 to 3	3	300
3	~~0,5 – 10~~ 10 to 1	~~0,5~~ 1	1 to 10	10	1 000
4	~~1 – 20~~ 30 to 3	~~1~~ 3	3 to 30	30	3 000 [b]
X (harsh)	Case-by-case according to the situation				

NOTE Values in $V_{r.m.s.}$

[a] Values may be limited by ITU-T or other mandated mitigation methods.

~~[b] Level of disturbance decreases as frequency increases in range shown.~~

[b] May be limited by sparkover of clearances. On insulated ground circuits, higher voltages might occur.

[c] The disturbance levels decrease by 20 dB/decade.

[d] The disturbance levels increase by 20 dB/decade.

5.1.7 DC voltage in AC networks

DC voltage in AC networks is caused primarily by geomagnetic storms that may induce high levels of quasi–DC currents in the high-voltage network. DC currents as high as hundreds of amperes have been measured in high-voltage networks, thereby reducing voltages of up to 10 % of rated voltage for times of hundreds of seconds. In addition, harmonics are created in transformers, which propagate throughout the power network. As these events are rare (once per year) and regional (northern and southern latitudes), it is recommended that these events be considered as a very low probability at a particular location. It is noted that under severe circumstances, a voltage collapse of the entire power network can result.

It is difficult to assign a precise disturbance level to this rare phenomenon, however, class 3 harmonic levels in Table 2 and class 3 voltage fluctuations in Table 3 could be considered as appropriate for all locations connected to the public power supply network.

5.2 Radiated low-frequency phenomena

5.2.1 Magnetic fields

Magnetic fields in the power frequency range are produced by several types of sources:

– nearby power cables and lines, in particular overhead power lines
– stray fields from transformers
– bus bar systems
– switchgear installations
– power system ~~apparatus~~ equipment, such as power drive systems, rectifiers, generators, etc.

In the case of power cables, magnetic fields might occur also due to common mode currents, depending on the type of the power supply system (e.g. in the case of TN-C systems, see 8.6).

The frequencies or frequency ranges to be considered depend on the type of sources existing at the location under consideration and comprise:

- DC
- frequencies of railway traction system (e.g. DC, 16 2/3 Hz, 50 Hz, 60 Hz, ...)
- fundamental frequency of power supply systems
- harmonics occurring in a power system
- frequencies not related to power systems

Significant magnetic fields at harmonic frequencies appear only in special circumstances, for example in the presence of power electronic systems.

Case-by-case consideration is required in presence of particular nearby high power equipment (electrolysis, generators, etc.), within high power installations (switchyards, power stations, etc.) or for particular types of equipment (magnetic resonance ~~apparatus~~ equipment, induction heating, etc.). Table 9 quantifies the magnetic fields from various low-frequency sources.

Table 9 – Disturbance degrees and levels for low-frequency magnetic fields at various frequencies

Disturbance degree	Phenomena (sources)				
	DC [a]	Railway frequency ~~16 2/3~~ 16,7 [b, f]	Power system frequency 50/60 Hz [c]	Harmonics of power system 0,1 kHz to 3 kHz [d]	Not related to power systems [e]
	Disturbance levels				
A (controlled)	Case-by-case according to the equipment requirements				
1	3	1	3	3/n	0,015
2	10	3	10	10/n	0,05
3	30	10	30	30/n	0,15
4	100	30	100	100/n	0,5
X (harsh)	Case-by-case according to the situation				

NOTE Values in A/m, ~~DC or~~ r.m.s. for AC.

[a] In addition to earth magnetic field of about 20 A/m to 60 A/m, depending on location, at 1 m above ground.

[b] At 20 m from the track. The fields increase considerably the closer they get to the tracks. 1 A/m at 20 m, 1 m above ground, corresponds to a locomotive of about 3 000 kW. Some types of railway track signalling systems can also give rise to field strengths greater than level 1.

[c] For overhead lines, measured at 1 m above ground. For household or commercial environments, measured at 0,3 m from the source, the magnetic field has a range of magnitude of 1 A/m to 10 A/m.

[d] Where n is the order of the harmonic.

[e] Where audio-frequency inductive loops are present, the long-term average field strength in the frequency range 100 Hz to 5 kHz may be 0,1 A/m (level 3), see IEC 60118-4.

[f] Applicable also to railway systems with fundamental power frequencies other than 16,7 Hz.

5.2.2 Electric fields

Significant electric fields appear in the vicinity of conductive structures that have a high voltage with respect to ground potential or with respect to other conductive structures. Typical situations are for example high-voltage overhead power lines or air-insulated substations. Considering a potential impact by electric fields, cables are much less important than overhead lines due to the fact that both the metallic coating and the soil isolate the electric field nearly totally.

The electric field strength increases proportionally to the nominal voltage of the high-voltage conductors. The electric field strength at 1 m height above ground under typical high-voltage overhead lines ranges from a few kV/m to approximately 15 kV/m for voltage levels from 110 kV up to 750 kV.

Equipment that is located within buildings experiences much lower electric field strength because buildings provide a reduction factor of 10 to 20, or an even higher attenuation if such buildings are mainly constructed with conductive elements.

Electric fields caused by household appliances are generally very small and are existent in close proximity to the surface of such appliances.

Table 10 quantifies the electric fields from various low-frequency sources.

Table 10 – Disturbance degrees and levels for low-frequency electric fields

Disturbance degrees	Phenomena (sources)		
	DC lines (transmission or traction)	Railway frequency ~~16 2/3~~ 16,7 Hz lines [a]	Power frequency 50/60 Hz lines
	Disturbance levels		
A (controlled)	Case-by-case according to the requirements		
1	0,1	0,1	≤0,1 [b]
2	1,0	0,3	≤1,0 [c]
3	10	1,0	≤10 [d]
4	20	3,0	≤20 [e]
X (harsh)	Case-by-case according to the situation		

NOTE Values in kV/m, ~~DC or~~ r.m.s. for AC; values are typical for a height of 1 m above ground.

[a] Applicable also to railway systems with fundamental power frequencies other than ~~16 2/3~~ 16,7 Hz.

[b] Residential environment, far from overhead lines.

[c] Outdoor, below overhead lines up to 30 kV and indoor, below overhead lines up to 765 kV.

[d] Outdoor, below overhead lines up to 400 kV.

[e] In HV stations up to 400 kV and below overhead lines up to 765 kV.

NOTE 1 Information about electric field coupling is given in IEC TR 61000-2-3.

NOTE 2 There is no basic immunity standard available that reflects this kind of electromagnetic stress because significant low-frequency electric fields occur in some specific situations and the amount of electromagnetic disturbances coupled into equipment by this phenomenon is generally low so that in most cases no harmful interference is produced.

6 High-frequency electromagnetic phenomena

6.1 Conducted high-frequency phenomena

6.1.1 General

This type of disturbance is generally considered as occurring within the set of conductors of a system, either in the power supply (AC or DC) or the signal lines of the many types used in modern equipment. A frequent situation is when these systems are implemented by separate organizations or different individuals, without consideration of voltage differences that might occur between physically close conductors of different systems, hence the consideration of ground coupling path (or reference) is one of the media in which a disturbance can occur.

These disturbances can be divided into two major types, each characterized by a set of attributes, as follows:

1) continuous phenomena (induced CW) attributes:
   - amplitude
   - frequency
   - modulation
   - source impedance

   } voltage and current

2) transient phenomena (unidirectional or oscillatory) attributes:

- rate of rise
- duration
- amplitude
- spectrum
- rate of occurrence
- frequency
- source impedance
- energy potential

} voltage and current

When a cable contains an imperfect external shield such as a braid, incident electromagnetic fields will induce voltages and currents (depending on loads) on the external shield relative to the ground (common mode coupling). Due to transfer impedance and admittance terms for a given cable, there can be leakage into the interior cable wiring, inducing voltages and currents (depending on loads) between pairs of wires (differential mode coupling). This simple example describes the conversion process. It should be noted that differential mode signals can also be converted to common mode signals in the reverse process, creating electromagnetic emissions from the common mode currents.

Clause 6 provides a detailed table for each of the conducted disturbances (continuous or transient) listed in Table 1. Each table gives appropriate degrees that will be selected for a definition of the environment at the various location classes.

6.1.2 Direct conducted CW phenomena

6.1.2.1 General

~~There are a number of devices that produce direct conducted CW phenomena as a result of their intended function. Generally, these devices make a limited contribution to the electromagnetic environment due to their low deployment density and/or time-limited use. An example of such a device is the baby alarm that uses the home LV power distribution infrastructure to connect the two parts of the baby alarm system: such a device is limited in application (i.e. used only within houses with new-born children) and limited in time (typically being used for a few hours each day during the first few months of the child's life).~~

~~PLT is however very different: it has the potential for high deployment densities and permanent (i.e. 'always on') use. Hence the following sub clause specifically addresses this technology.~~

Equipment exists that produces direct conducted CW phenomena as a result of its functional principle or intended function. Basically, two types of conducted disturbances can be distinguished:

- Intentional signal voltages used, for example, for mains signalling, such as PLC communication. Although these voltages are intentionally generated for communication purposes, they act as potential interference sources for all the items of equipment connected to the same power supply network but are not part of the communication process.
- Unintentional disturbance voltages due to functional principles of the equipment under consideration, for example, the voltages at the switching frequency and its integer multiples in case of power electronic devices (i.e. power supplies, power drive systems, uninterruptable power supply, etc.).

The mechanisms behind the generation of those disturbances imply that they are predominantly of differential mode type as the disturbance source acts between the conductors of a supply cable. Due to the unbalanced termination of equipment involved in the generation and propagation of those disturbances common mode disturbances are also produced to a certain extent.

The levels of disturbances associated with the first type of conducted disturbances are generally limited due to the fact that corresponding communication equipment has to fulfil the requirements for maximum signal levels given in various standards. With regard to the frequency range in which these communication systems operate, two frequency ranges can be distinguished:

– below 150 kHz applied for example for mains signalling used by utilities in energy measurements or by private network users' mains communicating systems (see 5.1.4),
– above 150 kHz for example for wide band communication over the internet (see 6.1.2.3 and 6.1.2.4).

6.1.2.2 PLT

At the time of publication of this document, PLT technology is not a standardised technology, rather it is a proprietary technology developed separately by a number of manufacturers. Hence a number of key technology parameters differ between manufacturers and have been subject to some change over time and may continue to change. Such key parameters include:

– the frequencies over which the technology transmits/receives;
– the PSD at which transmission is launched onto the LV power distribution installation;
– power management ability (i.e. is the technology 'always on' – transmitting constantly, even when there is no data payload to transfer – or can the technology cease transmission during such times and enter a low-power mode?);
– the digital modulation scheme employed.

As PLT transmits information over lines that are designed only for power transfer and not for information transfer, the technology has the potential to disturb all radio services in the neighbourhood and in fact to cause a worldwide increase of the general background noise in this frequency range.

Generally the technology transmits over a frequency band between ~~∼2~~ 1,606 5 MHz and ~~30~~ 87,5 MHz.

Also, the technology has not yet reached the level of maturity associated with a set of open interoperability requirements: hence the only items that can be expected to interoperate are those from the same manufacturer that employ exactly the same variant.

6.1.2.3 'In-home'

'In-home' PLT systems are designed to exploit a building's existing LV power distribution installation as a common data bus to enable the bi-directional transfer of digital data at rates up to ~~≈100 Mbps~~ 1 200 Mb/s. This exploitation of existing building installation is a significant benefit, as it avoids the invasive and disruptive installation of a purpose-built data transfer network and allows individual items to be networked together within the same building. The data being transferred can originate from outside the building: PLT can therefore be used to distribute high-speed internet services delivered to the building via traditional UTP telephony cable, co-axial TV cables or optical fibre connection. The data being transferred can also originate from within the building: PLT can therefore be used to allow PCs to communicate with various peripherals such as shared printing resources, shared storage resources, etc.

Transfer of data is achieved by the location of a minimum of two terminal items at power sockets connected to the LV power distribution installation.

PLT technology creates both a conducted and radiated disturbance to the local electromagnetic environment.

The first conducted disturbance arises as a result of the technology's treatment of the LV power distribution installation as a common data bus: all other electrical and electronic items connected to the building's LV power distribution installation will be exposed to a simultaneous common mode and differential mode conducted disturbance through the AC port. The differential mode generally dominates, as this is the intentionally launched transmission (albeit attenuated as a result of its propagation along the LV power distribution installation); the common mode disturbance is generally of a lower disturbance level, since this arises as a result of modal conversion of the launched differential mode disturbance by the unbalance about earth of the LV power distribution installation.

The second conducted disturbance arises as a result of electromagnetic coupling between a building's internal LV power distribution installation and its telephony distribution installation: all other items connected to the building's telephony distribution installation (i.e. voice telephony items, data modems, fax machines, etc.) will be exposed to a simultaneous common mode and differential mode conducted disturbance through the signal port. The common mode disturbance generally dominates, as this is the result of the coupling between the power and telephony distribution installation; the differential mode disturbance is generally of lower disturbance level, since this arises as a result of modal conversion of the coupled common mode disturbance by the unbalance about earth of the telephony distribution installation.

Both conducted disturbances are able to propagate along the external LV distribution and telephony installation connected to the building. Depending upon the topology of these external networks, these disturbances may be able to propagate to adjacent buildings, where it is possible that they may interfere with in-home PLT equipment from other manufacturers.

The radiated disturbance is produced by the common mode current that is induced upon the building's LV power and telephony distribution installations. This common mode disturbance is free to propagate throughout the building's distribution installation and along the external infrastructure connected to the building.

At the time of publication of this document, some proprietary techniques are under development to mitigate the impact of this radiated disturbance on broadcast reception. The techniques involve the PLT technology attempting to detect the existence of radio services within its immediate environment (by scanning the common mode or differential mode signals present on the LV power distribution installation for carriers displaying specific modulation schemes) and dynamically adjust ('notch') its launched PSD around the identified radio services. At the time of publication of this document no disturbance levels are available.

6.1.2.4 CW disturbances from infeed converters and active infeed converters (AICs)

Infeed converters and AICs are as part of their design installed and connected between the electric power supply AC and a secondary DC side. They can be found everywhere in home, residential, small office and industry environments for feeding DC consumers, for example screens, charging devices, communication units, photovoltaic converters, etc. Typically the infeed converters are installed in voltage networks with a nominal voltage of 690 V or below.

The design of infeed converters and AICs is intended to avoid low frequency harmonics by synthesizing sinusoidal AC currents. In order to achieve sinusoidal input currents the DC-link voltage is switched with a pulse frequency of normally between 300 Hz and 150 kHz. This switching generates unintended emissions of noise on the AC side.

The amount of and total emissions are dependent on several factors:

- design of the converter, especially of the filter design on the AC side
- load or no-load conditions of the connected DC side
- the number of converters on a single branch of a power supply and the degree to which their emissions differ from each other by magnitude and phase angle

- degradation of the filter capacitors because of aging
- spectrum of the emission and the frequency-dependent electromagnetic fields with inductive, capacitive and galvanic coupling to neighboring networks
- resonances in the supply network
- stability of the supply network characterized by the impedance of the supply network

Other effects which should be taken into account are non-sinusoidal input voltages resulting from other devices or from the generating unit. These will cause additional currents flowing in the capacitances within the filters of infeed converter/AIC.

The parallel installation of infeed converters can cause tripping of internal or external fuses. This results from currents within the filtering capacitors and can reach values of ten times the rated current of the infeed converter.

Infeed converters are designed to produce an AC current waveform that fulfils the emission requirements. Thus the waveform may still be significantly deformed due to the restrictions of the equipment. AICs, on the contrary, usually have quite sinusoidal current and some of them may have even active filter functionality that reduces the voltage harmonics of the supply network by producing counteracting emissions.

Side effects of infeed converters and AICs are harmonic distortions near the pulse frequency and multiples of it.

Impedances of the supply network are often assumed to be constant. In practice large hourly variations can be caused by changing loads in the network. Especially, reactive power compensating capacitors may significantly change the resonances in the network when they are switched on or off.

Power drive systems can also be equipped with an AIC. The power rating of such drives may be quite high and thus their unintended emissions may be increased similarly.

The emissions of the infeed converters can result in a relatively large bandwidth of disturbances affecting electric and electronic devices connected to the same or adjacent networks. Because the main function of converters is to convert voltages and frequencies disturbing effects may not be obvious to the user. Detailed information about emissions from power drive systems is given in IEC TS 62578. These data were used to conclude on the levels of disturbances as given in Table 11.

Table 11 – Disturbance degrees and levels of direct CW voltages

Disturbance degree	9 kHz to 150 kHz
A (controlled)	Case-by-case according to the equipment requirements
1	0,3 V
2	1 V
3	3 V
4	10 V
5	30 V
X (harsh)	Case-by-case according to the situation

NOTE 1 Values are r.m.s.

NOTE 2 The corresponding immunity test is given in IEC 61000-4-19.

6.1.2.5 Differential mode continuous wave

The disturbance sources described above predominantly generate differential mode disturbances. However, due to unbalances in the equipment and propagation, common mode disturbances are produced as well with significant conversion from differential to common mode particularly in the frequency range above 150 kHz. The situation with respect to common mode disturbances is described in 6.1.3.

For the characterization of differential mode disturbances the following aspects can be considered:

– Disturbances produced by signalling systems might reach maximum amplitudes derived from functional specification of signalling systems. Such specifications are given for example in EN 50065-1.
– Disturbances produced by power electronics can be derived from measurement data.

At this time, the collection of corresponding data is ongoing. Preliminary disturbance levels can be found in the corresponding basic immunity standard IEC 61000-4-19.

6.1.3 Induced continuous wave

Electromagnetic fields (for example produced by intentional transmitters or adjacent cabling of power electronics) induce voltages with respect to reference ground on conductors exposed to these fields. The amplitude of the induced voltage depends on the length of the conductor, its height above ground, loops formed by stray capacitances and through other equipment, plus other factors.

The relationship between the field strength and the induced voltage is nominally linear for lengths greater than a sixth of the wavelength. Resonance effects occur when the dimensions of the loop approach a quarter wavelength and multiples thereof. Table 12 gives values of induced voltages and corresponding values of common mode currents calculated by assuming a characteristic impedance with respect to a ground reference of 150 Ω (common mode impedance of the mains can be much lower than 150 Ω).

The degrees in Table 12 are for unmodulated conditions. Normally occurring disturbance signals are amplitude modulated (typically less than 80 % modulation) or frequency modulated.

Table 12 – Disturbance degrees and levels of induced CW voltages with respect to reference ground

Disturbance degree	10 kHz to 150 kHz [a] 0,15 MHz to 150 MHz	
	V	mA
A (controlled)	Case-by-case according to the equipment requirements	
1	0,3	0,7
2	1	7
3	3	21
4	10	70
5	30	210
X (harsh)	Case-by-case according to the situation	

NOTE 1 Values are r.m.s.

NOTE 2 The frequency range from 10 kHz to 150 kHz is covered by IEC 61000-4-16, 150 kHz to 80 MHz is covered by IEC 61000-4-6.

[a] Some VLF transmitters can induce considerably higher voltages in the 10 kHz to 150 kHz range.

6.1.4 Transients

For the purpose of this classification, high-frequency transient phenomena have been divided into two groups, unidirectional and oscillatory. For each group, several different phenomena (and related sources) are responsible for the occurrence of these disturbances.

1) Oscillatory transients: The relatively high frequency of oscillation of these transients ranges from less than 1 kHz (primarily capacitor switching) to several MHz (primarily local oscillations, disconnect switching). Those at the higher end of the frequency range usually have limited energy deposition capability, but can have high peak voltages. Those at the lower end of the frequency range can have higher energy deposition capability but lower peak voltages.

2) High-energy transients: The various waveforms of these transients are generally accepted as representing appropriate stress levels associated with nearby direct lightning discharges or switching/fuse operation:
   - lightning surges on overhead and underground distribution systems;
   - lightning surges originating on overhead lines and travelling in cables;
   - transients generated by switching and fuse operations involving trapped energy in the inductances of the power systems and related/connected equipment.

3) Very fast transients: These transients occur as single events such as electrostatic discharges (although these might involve a brief sequence of several single pulses), or as bursts associated with local low inductance load switching. Both involve very little energy but are capable of producing serious interference or upset due to the extremely fast rise time of the event. The transient bursts have been associated with arcing phenomena under the label of "showering arc" or "electrical fast transient" (EFT). Dielectric breakdown is also a source of similar high-frequency disturbances.

4) Coupled disturbances: Radiated waves can also be coupled into wiring systems and propagate further into equipment; at a point of use far away from the point of coupling, these disturbances then appear as conducted disturbances, although their origin is radiated energy. These coupled disturbances include several transients induced by the electromagnetic fields from a nearby (but not attached) cloud-to-ground lightning flash, which may contain 2 strokes to 20 strokes, and will contain energy in the kilohertz to megahertz frequency range. A second major source of these disturbances is due to the coupling of radiated fields from disconnect switches in power substations; these very fast rising fields induce an oscillatory voltage in cables at frequencies as high as tens of MHz.

For each waveshape selected as one of the possible representations of the transient environment, the peak open-circuit voltage and the peak short-circuit current of the source shall be stated to provide a complete and meaningful description.

Occasionally, attempts are made to describe (classify) transients in terms of "energy" to help select the rating of a candidate surge protective device. However, this concept can be a misleading oversimplification because the energy distribution among the circuit elements involved in a transient event depends on the impedance of the source (including the AC mains network) as well as on the impedance of the surge protective device called upon to divert the transient. There is no independent, meaningful, self-contained description of a transient in terms of energy alone. The energy delivered to the end equipment is the significant factor, but it depends on the distribution between the source and the load (equipment or surge-diverting protective device, or both).

Table 13 and Table 14 are structured with three sets of time scale or frequency range to recognize these diverse origins and provide a generic description of their significant attributes. The disturbance degrees are expressed as open-circuit voltages, meaning the voltage expected under typical light-load conditions, without any nearby surge protective device. For phenomena that reflect the wiring geometry and coupling modes of the transient source, the voltages are shown in V, in a first approximation, independently of the system voltage. For the switching transients (capacitor and fault clearing), the transients are directly proportional to the system voltage and, therefore, the voltages are shown as multiples of the peak value of the power frequency voltage.

Table 13 – Disturbance degrees and levels for conducted unidirectional transients in low-voltage AC power systems

Disturbance degrees	**Phenomena (sources)**			
	Contact arcing [a]	Lightning < 1 km [a]	Lightning > 1 km [a]	Fuse operation [b]
	Unidirectional transients time-scale			
	Nanoseconds	Microseconds		Milliseconds
	5 ns [c] 50 ns [d] Bursts [e] ms [f] 50 Ω [g]	1 µs [c] 50 µs [d] Multiple [e] ms [f] 1 Ω to 10 Ω [g]	10 µs [c] 1 000 µs [d] Multiple [e] s [f] 20 Ω to 300 Ω [g]	0,1 ms [c] 1 ms [d] Rare [e] Single [f] 0,2 Ω to 2 Ω [g]
	Disturbance levels			
A (controlled)	Case-by-case according to the equipment requirements			
1	0,5 kV	1 kV	0,5 kV	None
2	1 kV	2 kV	1 kV	0,5 U_{peak}
3	2 kV	4 kV	1,5 kV	1,0 U_{peak}
4	4 kV	8 kV	2 kV	2,0 U_{peak}
X (harsh)	Case-by-case according to the situation			

[a] Values shown are open-circuit peak voltages (that is, no large loads connected at the time of occurrence, nor any surge protective devices installed in the system) for 120 V to 690 V r.m.s. power systems. They reflect the external origin and the coupling mechanisms of these transients, which are independent of the system voltage. These are currents carried by the power conductors in the building, not the external lightning current; a direct strike to the building may cause larger currents in the power conductors.

[b] Values shown are open-circuit voltages for transients occurring at the peak of power frequency sine wave (U_{peak}), added to the power frequency voltage.
These transients which are internally generated are essentially proportional to the system voltage.

[c] Rise time. Initial rise time of the transient.

[d] Duration. Full width at half maximum of the individual transient.

[e] Rate of occurrence.

[f] Duration of event. The order of magnitude for the total duration of an event with multiple transients is expressed in the units shown.

[g] Source impedance.

Table 14 – Disturbance degrees and levels for conducted oscillatory transients in low-voltage AC power systems

Disturbance degrees	Phenomena (sources)		
	Local system response to impulsive disturbance [a]	Building response to impulsive disturbance [a]	Capacitor switching [b]
	Oscillatory transients frequency range		
	High frequency 0,5 MHz to 30 MHz	Medium frequency 5 kHz to 500 kHz	Low frequency 0,2 kHz to 5 kHz
	5 ns to 50 ns [c] 0,5 ns to 5 µs [d] Frequent [e] 50 Ω to 300 Ω [f]	0,5 µs [c] 20 µs [d] Occasional [e] 10 Ω to 50 Ω [f]	1,5 µs [c] 3 ms [d] Infrequent [e] 10 Ω to 50 Ω [f]
	Disturbance levels		
A (controlled)	Case-by-case according to the equipment requirements		
1	0,5 kV	1,0 kV	0,5 U_{peak}
2	1,0 kV	2,0 kV	1,0 U_{peak}
3	2,0 kV	4,0 kV	2,0 U_{peak}
4	4,0 kV	6,0 kV	3,0 U_{peak}
X (harsh)	Case-by-case according to the situation		

[a] Values shown are open-circuit voltages (that is, no large loads connected at the time of occurrence, nor any surge protective devices installed in the system) for 120 V to 690 V r.m.s. power systems. They reflect the external origin and the coupling mechanisms of these transients, which are essentially independent of the system voltage.

[b] Values shown are open-circuit voltages, for transients occurring at the peak of power-frequency sine wave, including the power-frequency voltage. These transients, which are internally generated, are essentially proportional to the system voltage.

[c] Rise time. Initial rise time of the first part of the transient.

[d] Duration. Full width at half maximum of the envelope of the transient.

[e] Rate of occurrence.

[f] Source impedance.

6.2 Radiated high frequency phenomena

6.2.1 General

The description of radiated electromagnetic environments is based on the evaluation of three types of phenomena, each being a category of waveforms sharing some common time domain or frequency domain properties, as follows:

– radiated (continuous wave) oscillatory disturbances;

– radiated (modulated) signal disturbances;

– radiated (transient) pulsed disturbances.

Each type contains waveforms that can be reasonably well characterized with a limited number of parameters, thanks to their similarity. A given electromagnetic phenomenon might belong to only one type, or be considered as the superposition of several waveforms belonging to different types.

A given radiated electromagnetic environment can be described with an acceptable accuracy, by using these three types, and also considering the wave impedance (near-field and far-field effects). The definition of each type is given in 6.2.2 to 6.2.4, with tables showing disturbance degrees. The rationale for splitting a single reality – the radiated electromagnetic environment at a given location – into several types, is that the action of different types on the item can have different mechanisms and different consequences. Table 15 gives an overview of the radiation sources which are considered.

Table 15 – Radiation sources

Table	Type of source
16	Radiated continuous oscillatory disturbances
17	Amateur radio bands below 30 MHz
18	27 MHz CB band
19	Analogue communication services below 30 MHz
20	Analogue communication services above 30 MHz
21, 22	Mobile and portable units of cellular phones
23, 24	Base stations of cellular phones
25	Medical and biological telemetry items
26, 27, 28	Digital television broadcast (VHF and UHF)
29, 30	Unlicensed radio services
31	Amateur radio bands above 30 MHz
32	Paging service base station
33 to 38	Other RF items
39, 40	RFID and railway transponder systems
41	Radiated pulsed disturbances
42	RADAR systems

In the past, electromagnetic fields were predominantly generated by fixed transmitters, for example by radio or TV broadcasting transmitters. Recently, handheld, frequency-modulated (FM) transceivers for business, public safety, and amateur radio communications became a significant part of those RF applications. However, distribution was limited (e.g. by licenses) and in most cases the radiating antennas were outside buildings to get a high efficiency. The situation changed once technology allowed manufacturing of compact wireless phones with low weight and a reasonable price. Wireless services (DECT, landline telephones, mobile phones, UMTS/WiFi/WiMAX/Bluetooth, baby monitors, etc.) have come into widespread use and acceptance. Recognizing the fact that equipment for these new technologies could have the antenna inside buildings and be omnipresent at work, in the home and in public transportation creates a new situation for exposure of equipment to RF energy.

With the new digital technologies, the traditional modulation format of AM and FM has given way to pulse modulation. While overall time-averaged transmit power levels might have generally decreased over time due to improved network density and migration of services, the maximum possible (peak pulse) power levels in other bands have increased significantly. Moreover, the incorporation of multiple transmitting antennas (to support for example WiFi and Bluetooth links), evolving form factors, higher bit rates to facilitate data transfer and Internet access and the use of wireless headsets have resulted in a more complex and diverse pattern of use and exposure.

With respect to the exposure to those various types of electromagnetic fields, two situations have to be distinguished: equipment is exposed to an electromagnetic field under far field conditions or under near-field conditions, respectively. The second situation in particular has increased significantly in the recent past. Hence Tables 16 to 19, giving disturbance levels for various types of transmitters, consider both situations.

It should be noted, that the well-established immunity test method in the basic immunity standard IEC 61000-4-3 simulates the thread due to electromagnetic fields mostly under far field conditions. However, it turned out that equipment could have different immunity characteristics for exposure under near-field conditions. A corresponding immunity test method is currently being worked out in the framework of the basic immunity standard IEC 61000-4-39.

6.2.2 Radiated continuous oscillatory disturbances

These disturbances, occurring as single or multiple events, can strongly couple with the item, because of an intentional selectivity, or because of an unintentional resonant coupling mechanism. The values encountered in practice strongly depend on the distance between victim and source (see Table 16 and Annex B for more information). Disturbances from modulated sources (e.g. mobile phones, CB radio) are dealt with in 6.2.3.

Table 16 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Radiated continuous oscillatory disturbances

Disturbance degree and corres-ponding field strength	**Phenomena (sources)**		
	ISM Group 2 equipment	ISM Group 2 equipment	ISM Group 2 equipment
	Transmitter frequencies [MHz]		
	6,765 to 6,795 [a] 13,553 to 13,567 26,957 to 27,283	40,66 to 40,70 433,05 to 434,79 [a] 902 to 928	2 400 to 2 500 5 725 to 5 875 24 000 to 24 250 61 000 to 61 500 [a] 122 000 to 123 000 [a] 244 000 to 246 000 [a]
	~~**Disturbance level and**~~ **Distance to source** [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 0,3 V/m	d [b]	d [b]	d [b]
2 1 V/m	d [b]	d [b]	d [b]
3 3 V/m	d [b]	d [b]	d [b]
4 10 V/m	d [b]	d [b]	d [b]
5 30 V/m	d [b]	d [b]	d [b]
X (harsh)	Case-by-case according to the situation		

[a] There are no limits for those frequencies and frequency bands for radiated disturbances (see CISPR 11).

[b] ISM group 2 equipment (according to CISPR 11) is not limited in the power used for the operation and therefore there are no limits to be observed for radiated disturbances with regard to EMC. Hence it is not possible to generally calculate distances d.

6.2.3 Radiated modulated disturbances

6.2.3.1 Radiated modulated disturbances below 30 MHz

Electromagnetic fields below 30 MHz are mainly due to the usage of amateur radio systems, CB equipment and AM broadcasting.

The power values mentioned in Table 17 are a summary of all frequencies and the maximum allowed output power of the transmitter given as P_{PEP} (peak envelope power) of all three ITU regions. The output power used for the calculation of the distances in the table is P_{PEP} multiplied by the theoretical antenna gain of a half-wavelength dipol antenna (2,15 dB) and is given as P_{EIRP} (equivalent isotropically radiated power). Possible losses from cables, switches and mismatches are not considered, to keep the model as simple as possible. The calculated field strength is only valid for the main beam of the antenna and is lower outside this beam.

The distances may vary in real situations because the typical antenna gain is different (up to 10 dB or more) and losses (e.g. from cables) have to be taken into account. These (mostly rotatable) high gain antennas are normally mounted on antenna towers 10 m to 30 m above ground or on a roof. In this case only in the direction of the main beam of the antenna the full field strength will occur. Even for slight deviations from the direction of maximum beam strength significant reductions of the antenna gain are observed.

Table 17 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Amateur radio bands below 30 MHz

Disturbance degree and corresponding field strength	**Phenomena (sources)**		
	Amateur radio station P = 1 W_{ERP}	Amateur radio station ~~P = 1 500 W (ERP) [a]~~ P = 100 W_{PEP} [a] P_{EIRP} ≈ 164 W [a] (for 5 MHz band P = 50 W_{ERP}) [e]	Amateur radio station P = 1 500 W_{PEP} [a] P_{EIRP} ≈ 2 500 W [a]
	Transmitter frequencies [MHz]		
	0,135 7 to 0,135 8 [b] 0,135 7 to 0,137 8 [c] 0,472 to 0,479 [d]	1,8 to 2,0 3,5 to 4,0 5,330 5; 5,366 5, 5,371 5; 5,403 5 7,0 to 7,3 10,1 to 10,157 3 14,0 to 14,350 18,068 to 18,168 21,0 to 21,45 24,890 to 24,990 28,0 to 29,7	1,8 to 2,0 3,5 to 4,0 5,330 5; 5,366 5, 5,371 5; 5,403 5 7,0 to 7,3 10,1 to 10,157 3 14,0 to 14,350 18,068 to 18,168 21,0 to 21,45 24,890 to 24,990 28,0 to 29,7 ~~[b]~~
	~~**Disturbance level and**~~ **Distance to source** [m]		
A (controlled)	Case-by-case according to the equipment requirements		
~~1~~	~~0,3 V/m~~ ~~d m [b]~~	~~0,3~~ ~~905~~	~~0,3~~ ~~905~~
~~2~~	~~1~~ ~~d~~	~~1~~ ~~271~~	~~1~~ ~~271~~
~~3~~	~~3~~ ~~d~~	~~3~~ ~~90,5~~	~~3~~ ~~90,5~~
~~4~~	~~10~~ ~~d~~	~~10~~ ~~27,1~~	~~10~~ ~~27,1~~
~~5~~	~~30~~ ~~d~~	~~30~~ ~~9,05~~	~~30~~ ~~9,05~~
1 0,3 V/m	d [b]	233	905
2 1 V/m	d [b]	70	271
3 3 V/m	d [b]	23	90,5
4 10 V/m	d [b]	7	27,1
5 30 V/m	d [b]	2,3	9,05

X (harsh)	Case-by-case according to the situation

NOTE The above mentioned power and frequency bands are a summary of all three ITU regions. The power P is (if not otherwise mentioned) the allowed maximum output power of the amplifier (P_{PEP}). The power arriving at the antenna and effectively radiated by it is P_{ANT} and is P reduced by the losses of the feeding cable. For easy calculation of E and d, the effective isotropic power P_{EIRP} is useful. Most antennas have a direction with maximum radiation, i.e. in that direction they have a certain antenna gain G_{ISO} compared to an isotropic radiator. E and d of this maximum radiation can be easily calculated by means of P_{EIRP}, which is obtained by multiplying P_{ANT} by the isotropic antenna gain G_{ISO}. d is the spatial distance from the antenna.

In case of an amateur radio station many antenna types (and resulting antenna gains) are possible. The calculations for frequencies above 1,8 MHz in this table are done with an antenna gain of G_{ISO} = 2,15 dBi of a half-wavelength dipole antenna and assuming a lossless feeding cable.

Higher gains are possible, but these (mostly rotatable) antenna types are normally mounted on antenna towers 10 m to 30 m above ground. Typical values for G_{ISO} of such antennas are between 2 dBi and 10 dBi. In this case only in the direction of the main beam of the antenna the full field strength will occur. In other directions the field strength will be considerably reduced.

The same values for P_{EIRP} and therefore for E and d in the beam direction for the strong amateur station in the rightmost column could also be obtained with P = 500 W, a feeding cable attenuation of 1,5 dB and a directional antenna with an isotropic antenna gain G_{ISO} of 8,5 dBi. With the same P_{EIRP} the disturbing probability of such an antenna is much lower than that of an omnidirectional antenna, because the beam width is limited in the horizontal and vertical plane.

[a] To simplify the table the highest frequency for each column is used in the calculation of the distance. For frequencies below 7 MHz the result may be incorrect because the calculations are done for far field conditions.

[b] For this frequency band no calculations are done. The distances for 1 W_{ERP} (equivalent radiated power = standardized theoretical transmitting power taking into account system losses and antenna gain) are always in the near field and strongly depend on the antenna type used for transmission. Due to this fact the distances should be investigated case by case from measurements.

[c] In Australia.

[d] In Australia; used with P = 5 W_{ERP}

[e] For this frequency band no calculations are done to keep the table simple. The distances are much closer. The formulae in Annex B could be used to do the calculations if needed.

Table 18 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – 27 MHz CB band

Disturbance degree and corresponding field strength	Phenomena (sources)	
	CB mobile / portable P = 4 W (AM, FM) P = 12 W_{PEP} (SSB)	CB fixed installation P = 4 W (AM, FM) P = 12 W_{PEP} (SSB)
	Transmitter frequencies [MHz]	
	26,560 to 27,991	26,560 to 27,991
	~~**Disturbance level and**~~ **Distance to source** [m]	
A (controlled)	Case-by-case according to the equipment requirements	
1 0,3 V/m	63,2	80,5
2 1 V/m	18,9	24
3 3 V/m	6,32	8,1
4 10 V/m	1,89	2,4
5 30 V/m	0,63	0,81
X (harsh)	Case-by-case according to the situation	

NOTE The above mentioned power and frequency bands are a summary of all three ITU regions. In case of a CB radio station (fixed installation) many antenna types (and resulting antenna gains) are possible. The calculations are done with an antenna gain of 0 dB (0 dBi) for a mobile transmitter and with 2,15 dB (0 dBd) for a fixed station.

Table 19 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Analogue communication services below 30 MHz

Disturbance degree and corres-ponding field strength		Phenomena (sources)
		AM broadcasting P = 500 kW
		Transmitter frequencies [MHz]
		0,150 to 30
		~~Disturbance level and~~ **Distance to source** [m]
A	(controlled)	Case-by-case according to the equipment requirements
1	0,3 V/m	16 500
2	1 V/m	4 959
3	3 V/m	1 650
4	10 V/m	430
5	30 V/m	378,5
X	(harsh)	Case-by-case according to the situation

NOTE The distances are derived assuming an antenna gain of 2,15 dBi of a half wavelength dipole antenna and at the lowest frequency. The table provides data for the frequency range 0,150 MHz to 30 MHz for a 500 kW transmitter. Other power levels (50 kW to 2 500 kW) and antenna types (and resulting antenna gains) are also possible.

6.2.3.2 Radiated modulated disturbances above 30 MHz

Radiated electromagnetic fields from digital equipment such as cellular phones, digital television broadcast, and wireless LANs (local area networks) can be categorized to continuous and modulated disturbances. The broadcast services caused by the digital dividend after digital television transition are also categorized to this disturbance. Radiated disturbances of interest in 6.2.3.2 are classified into pulsed disturbances such as a spread spectrum and multi-carrier disturbances such as an OFDM (orthogonal frequency division multiplexing). A part of the modulation may be due to very frequent (several times per second) adjustments of the transmit power or due to the use of time domain multiple access (TDMA). In this last example the modulated carrier is active in short bursts resulting in a 100 % AM envelope repeated several times per second. A modulated disturbance has both the pulse and the oscillatory characteristics. A common factor is a continuous signal. Table 20 to Table 38 give information about various radiation sources and the connected range of disturbance degrees.

Further technical details about the various radiation sources are given in Annex B.

Table 20 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Analogue communication services above 30 MHz

Disturbance degree and corresponding field strength		Phenomena (sources)			
		Walkie-talkie P = 5 W	TV – VHF P = 320 kW	FM broadcast P = 100 kW	TV – UHF P = 500 kW
		Transmitter frequencies [MHz]			
		30 to 1 000	48 to 223	76 to 108	470 to 853
		Distance to source [m]			
A	(controlled)	Case-by-case according to the equipment requirements			
1	0,3 V/m	~~52,2 m~~ 40,7	13 220	7 390	16 500
2	1 V/m	~~15,6~~ 12,2	3 965	2 216	4 950
3	3 V/m	~~5,2~~ 4,1	1 322	739	1 650
4	10 V/m	~~1,57~~ 1,22	396,5	221,6	495
5	30 V/m	~~1,09~~ 0,41	132,2	73,9	165
X	(harsh)	Case-by-case according to the situation			

NOTE 1 The distances for all fixed services are derived assuming an antenna gain of 2,15 dBi of a half wavelength dipole antenna and at the lowest frequency. The data provided in the table represent typical analogue communication services. Different antenna types (and resulting antenna gains) are possible.

NOTE 2 The distances for the mobile service (walkie-talkie) are derived assuming an antenna gain of 0 dBi of an isotropic antenna at the lowest frequency.

Table 21 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Mobile and portable phones

Disturbance degree and corresponding field strength		Phenomena (sources)							
		GSM P = 2 W (portable) P = 20 W (obile)	DCS1800 P = 4 W	DECT P = 0,25 W	CT-2 P = 0,01 W	~~PDC~~ ~~P = 0,8 W (Portable) P = 2 W (Mobile)~~	PHS P = 0,08 W	NADC P = 6 W	IMT-2000 (TDD) (FDD) P = 0,25 W
		Transmitter frequencies [MHz]							
		890 to 915	1 710 to 1 784	1 880 to 1 960	864 to 868	~~940 to 955~~ ~~1 429 to 1 453~~	1 895 to 1 918	825 to 845	1 900 to 1 980
		Distance to source [m]							
A	(controlled)	Case-by-case according to the equipment requirements							
1	0,3 V/m	104	47	12	2,3	~~33~~	6,6	58	12
2	1 V/m	31	14	3,5	0,7	~~9,9~~	2,0	16	3,5
3	3 V/m	10,5	4,7	1,2	0,23	~~3,3~~	0,66	5,7	1,2
4	10 V/m	3,2	1,4	0,35	0,063	~~0,99~~	0,2	1,6	0,35
5	30 V/m	1,1	0,47	0,12	0,04	~~0,33~~	0,061	0,57	0,11
6	100 V/m	0,31	0,14	0,031	0,027	~~0,094~~	0,023	0,17	0,031
X	(harsh)	Case-by-case according to the situation							

NOTE 1 The output power, P, of each mobile or portable cellular is indicated by the maximum burst power, which means the average power within the burst signal.

NOTE 2 The calculation of distances is done with the maximum power indicated for that type of source.

Table 22 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Mobile and portable phones (continued)

Disturbance degree and corres-ponding field strength	**Phenomena (sources)**				
	3G/UMTS P = 21 dBm = 126 mW	3G/FOMA P = 24 dBm = 251 mW	3.5G/HSPA P = 24 dBm = 251 mW	3.9G/LTE P = 24 dBm = 251 mW	4G/LTE-A P = 23 dBm = 200 mW
	Transmitter frequencies [MHz]				
	a	b	c	d	450 to 470 698 to 862 790 to 862 2 300 to 2 400 3 400 to 3 600
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	8,3	12	12	12	10
2 1 V/m	2,5	3,5	3,5	3,5	3,1
3 3 V/m	0,83	1,2	1,2	1,2	1
4 10 V/m	0,24	0,34	0,34	0,34	0,29
5 30 V/m	0,073	0,1	0,11	0,1	0,11
6 100 V/m	0,044	0,047	0,045	0,047	0,067
X (harsh)	Case-by-case according to the situation				

NOTE 1 The output power, P, of each mobile or portable cellular is indicated by the maximum burst power, which means the average power within the burst signal.

NOTE 2 The calculation of distances is done with the maximum power indicated for that type of source.

NOTE 3 The frequency allocation and transmitting power of 5G (5^{th} generation mobile networks) is not determined yet because no international 5G development projects, such as 3GPP, have officially been launched. The standard for 5G will be released in the early 2020s. In 5G, broadband of around 1 GHz and a frequency allocation in the sub-millimeter band (e.g. 20 GHz) are considered. This table can be used to estimate the disturbance degrees of 5G cellular.

[a] Band II: 1 850 MHz to 1 910 MHz (uplink), 1 930 MHz to 1 990 MHz (downlink), US, CA
Band IV: 1 710 MHz to 1 785 MHz (uplink), 2 110 MHz to 2 155 MHz (downlink), US
Band V: 824 MHz to 849 MHz (uplink), 869 MHz to 894 MHz (downlink), US, AU, CA, BR
Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink), FI, TH, AU, JP
Band XI: 1 427,9 MHz – 1 447,9 MHz (uplink), 1 475,9 MHz – 1 495,9 MHz (downlink),JP
Band XIII: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink), US (planned)
Band XIV: 788 MHz to 798 MHz (uplink), 758 MHz to 768 MHz (downlink),US (planned)
Band XX: 832 MHz to 862 MHz (uplink), 791 MHz to 821 MHz (downlink), EU

[b] Band I: 1 920 MHz to 1 980 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), JP
Band VI: 830 MHz to 840 MHz (uplink), 875 MHz to 885 MHz (downlink), JP
Band IX: 1 749,9 MHz to 1 784,9 (uplink), 1 844,9 MHz to 1 879,9 (downlink), JP

[c] Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink)
Band IX: 1 749,9 MHz to 1 784,9 (uplink), 1 844,9 MHz to 1 879,9 (downlink)
Band XI: 1 427,9 MHz to 1 447,9 MHz (uplink), 1 475,9 MHz to 1 495,9 MHz (downlink)

[d] Band I: 1 920 MHz to 1 980 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), JP, KR
Band II: 1 850 MHz to 1 910 MHz (uplink), 1 930 MHz to 1 990 MHz (downlink), CA, Central and South America
Band III: 1 710 MHz to 1 785 MHz (uplink), 1 805 MHz to 1 880 MHz (downlink), JP (planned), HK, KR, EU
Band IV: 1 710 MHz to 1 785 MHz (uplink), 2 110 MHz to 2 155 MHz (downlink), US
Band V: 824 MHz to 849 MHz (uplink), 869 MHz to 894 MHz (downlink), KR
Band VII: 2 500 – 2 570 MHz (uplink), 2 620 MHz to 2 690 MHz (downlink), North Europe, HK, CN, CA, Central and South America
Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink), JP, KR, EU, Central and South America
Band X: 1 710 MHz to 1 770 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), EC, PE, UY
Band XI: 1 427,9 MHz to 1 447,9 MHz (uplink), 1 475,9 MHz to 1 495,9 MHz (downlink),JP
Band XII: 699 MHz to 716 MHz (uplink), 729 MHz to 746 MHz (downlink), US
Band XIII: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink), US (planned)
Band XIV: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink),US (planned)
Band XVII: 704 MHz to 716 MHz (uplink), 734 MHz to 746 MHz (downlink), US
Band XVIII: 815 MHz to 830 MHz (uplink), 860 MHz to 875 MHz (downlink), JP
Band XIX: 830 MHz to 845 MHz (uplink), 875 MHz to 890 MHz (downlink), JP
Band XX: 832 MHz to 862 MHz (uplink), 791 MHz to 821 MHz (downlink), EU
Band XXI: 1 447,9 MHz to 1 462,9 MHz (uplink), 1 495,9 MHz to 1 510,9 MHz (downlink),JP
Band XXIII: 2 000 MHz to 2 020 MHz (uplink), 2 180 MHz to 2 220 MHz (downlink),US
Band XXIV: 1 626,5 MHz to 1 660,5 MHz (uplink), 1 525 MHz to 1 559 MHz (downlink),US
Band XXV: 1 850 MHz to 1 915 MHz (uplink), 1 930 MHz to 1 995 MHz (downlink),US
Band XXVI: 814 MHz to 849 MHz (uplink), 859 MHz to 894 MHz (downlink), US
Band XXVIII: 703 MHz to 748 MHz (uplink), 758 MHz to 803 MHz (downlink), JP, AU, Central and South America
Band XXXVIII: 2 570 MHz to 2 620 MHz (uplink/downlink), EU
Band XL: 2 300 MHz to 2 400 MHz (uplink/downlink), AU, CN, IN
Band XLI: 2 496 MHz to 2 690 MHz (uplink/downlink), US, CN

Table 23 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Base stations

Disturbance degree and corresponding field strength	Phenomena (sources)							
	GSM P = 320 W_{ERP}	DCS1800 P = 200 W_{ERP}	DECT P = 0,25 W_{ERP}	CT-2 P = 0,25 W_{ERP}	~~PDC~~ ~~P = 96 W (ERP)~~	PHS P = 0,5 W_{ERP}	NADC P = 500 W_{ERP}	IMT-2000 (TDD) (FDD) P = 20 W_{ERP}
	Transmitter frequencies [MHz]							
	935 to 960	1 805 to 1 880	1 880 to 1 960	864 to 868	~~810 - 826~~ ~~1 477 - 1 501~~	1 895 to 1 918	870 to 890	1 900 to 1 920 2 110 to 2 170
	Distance to source [m]							
A (controlled)	Case-by-case according to the equipment requirements							
1 0,3 V/m	2 060	1 630	57	57	~~0,3~~ ~~1 130~~	81	2 590	520
2 1 V/m	620	490	17	17	~~1~~ ~~337~~	25	770	155
3 3 V/m	206	163	5,7	5,7	~~3~~ ~~113~~	8,1	259	52
4 10 V/m	62	49	1,7	1,7	~~10~~ ~~34~~	2,5	77	15,5
5 30 V/m	21	16	0,57	0,57	~~30~~ ~~11~~	0,81	26	5,1
6 100 V/m	6,2	4,9	0,17	0,17	~~100~~ ~~3,4~~	0,24	7,7	1,5
X (harsh)	Case-by-case according to the situation							

NOTE The output power, P, of each base station is indicated by the maximum burst power, which means the average power within the burst signal. An absolute gain of each base-station antenna is assumed to be 16,0 dBi. For instance, the case where there is a base station in a roof of a building is assumed. The fields are also calculated from Formula (B.4) in Annex B. In practice the resulting field strength can be much lower due to the placement and high directivity of the transmitting antennas.

Table 24 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Base stations (continued)

Disturbance degree and corres-ponding field strength	**Phenomena (sources)**				
	3G/UMTS P = 400 W (maximum value)	3G/FOMA P = 20 W	3.5G/HSPA P = 20 W	3.9G/LTE P = 10 W	4G/LTE-A P = 10 W
	Transmitter frequencies [MHz]				
	a	b	c	d	450 to 470 698 to 862 790 to 862 2 300 to 2 400 3 400 to 3 600
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	2 304	515	515	364	364
2 1 V/m	691	154	154	109	109
3 3 V/m	230	51,5	51,5	36	36
4 10 V/m	69	15,4	15,4	10,9	10,9
5 30 V/m	23	5,15	5,15	3,7	3,6
6 100 V/m	6,9	1,54	1,54	1,09	1,08
X (harsh)	Case-by-case according to the situation				

NOTE 1 The output power, P, of each base station is indicated by the maximum burst power, which means the average power within the burst signal. An absolute gain of each base-station antenna is assumed to be 16,0 dBi. For instance, the case where there is a base station in a roof of a building is assumed. The fields are also calculated from Formula (B.4) in Annex B. In practice the resulting field strength can be much lower due to the placement and high directivity of the transmitting antennas.

NOTE 2 The frequency allocation and transmitting power of 5G (5th generation mobile networks) is not determined yet because no international 5G development projects, such as 3GPP, have officially been launched. The standard for 5G will be released in the early 2020s. In 5G, broadband of around 1 GHz and a frequency allocation of sub-millimeter band (e.g. 20 GHz) are considered. At this moment, Table 23 can be used to estimate the disturbance degrees of 5G base station.

[a] Band II: 1 850 MHz to 1 910 MHz (uplink), 1 930 MHz to 1 990 MHz (downlink), US, CA
Band IV: 1 710 MHz to 1 785 MHz (uplink), 2 110 MHz to 2 155 MHz (downlink), US
Band V: 824 MHz to 849 MHz (uplink), 869 MHz to 894 MHz (downlink), US, AU, CA, BR
Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink), FI, TH, AU, JP
Band XI: 1 427,9 MHz to 1 447,9 MHz (uplink), 1 475,9 MHz to 1 495,9 MHz (downlink),JP
Band XIII: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink), US (planned)
Band XIV: 788 MHz to 798 MHz (uplink), 758 MHz to 768 MHz (downlink),US (planned)
Band XX: 832 MHz to 862 MHz (uplink), 791 MHz to 821 MHz (downlink), EU

[b] Band I: 1 920 MHz to 1 980 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), JP
Band VI: 830 MHz to 840 MHz (uplink), 875 MHz to 885 MHz (downlink), JP
Band IX: 1 749,9 MHz to 1 784,9 (uplink), 1 844,9 MHz to 1 879,9 MHz (downlink), JP

[c] Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink)
Band IX: 1 749,9 MHz to 1 784,9 MHz (uplink), 1 844,9 MHz to 1 879,9 (downlink)
Band XI: 1 427,9 MHz to 1 447,9 MHz (uplink), 1 475,9 MHz to 1 495,9 MHz (downlink)

[d] Band I: 1 920 MHz to 1 980 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), JP, KR
Band II: 1 850 MHz to 1 910 MHz (uplink), 1 930 MHz to 1 990 MHz (downlink), CA, Central and South America
Band III: 1 710 MHz to 1 785 MHz (uplink), 1 805 MHz to 1 880 MHz (downlink), JP (planned), HK, KR, EU
Band IV: 1 710 MHz to 1 785 MHz (uplink), 2 110 MHz to 2 155 MHz (downlink), US
Band V: 824 MHz to 849 MHz (uplink), 869 MHz to 894 MHz (downlink), KR
Band VII: 2 500 MHz to 2 570 MHz (uplink), 2 620 MHz to 2 690 MHz (downlink), North Europe, HK, CN, CA, Central and South America
Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink), JP, KR, EU, Central and South America
Band X: 1 710 MHz to 1 770 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), EC, PE, UY
Band XI: 1 427,9 MHz to 1 447,9 MHz (uplink), 1 475,9 MHz to 1 495,9 MHz (downlink), JP
Band XII: 699 MHz to 716 MHz (uplink), 729 MHz to 746 MHz (downlink), US
Band XIII: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink), US (planned)
Band XIV: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink),US (planned)
Band XVII: 704 MHz to 716 MHz (uplink), 734 MHz to 746 MHz (downlink), US
Band XVIII: 815 MHz to 830 MHz (uplink), 860 MHz to 875 MHz (downlink), JP
Band XIX: 830 MHz to 845 MHz (uplink), 875 MHz to 890 MHz (downlink), JP
Band XX: 832 MHz to 862 MHz (uplink), 791 MHz to 821 MHz (downlink), EU
Band XXI: 1 447,9 MHz to 1 462,9 MHz (uplink), 1 495,9 MHz – 1 510,9 MHz (downlink), JP
Band XXIII: 2 000 MHz to 2 020 MHz (uplink), 2 180 MHz to 2 220 MHz (downlink), US
Band XXIV: 1 626,5 MHz to 1 660,5 MHz (uplink), 1 525 MHz to 1 559 MHz (downlink), US
Band XXV: 1 850 MHz to 1 915 MHz (uplink), 1 930 MHz to 1 995 MHz (downlink), US
Band XXVI: 814 MHz to 849 MHz (uplink), 859 MHz to 894 MHz (downlink), US
Band XXVIII: 703 MHz to 748 MHz (uplink), 758 MHz to 803 MHz (downlink), JP, AU, Central and South America
Band XXXVIII: 2 570 MHz to 2 620 MHz (uplink/downlink), EU
Band XL: 2 300 MHz to 2 400 MHz (uplink/downlink), AU, CN, IN
Band XLI: 2 496 MHz to 2 690 MHz (uplink/downlink), US, CN

Table 25 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Medical and biological telemetry items

Disturbance degree and corresponding field strength		Phenomena (sources)			
		Tele-control (JP) P = 10 mW_{ERP}	Medical telemetry (JP) P = 10 mW_{ERP}	Wireless medical telemetry service (WMTS) (US) E = 0,2 V/m at 3 m [a]	Medical telemetry (ISM) P = 200 mW_{ERP}
		Transmitter frequencies [MHz]			
		426,025 to 469,487 5	420,05 to- 449,525	608 to 614	40,68
		Distance to source [m]			
A	(controlled)	Case-by-case according to the equipment requirements			
1	0,3 V/m	2,3	2,3	1,9	10
2	1 V/m	0,69	0,69	0,58	2,9
3	3 V/m	0,21	0,21	0,18	1,1
4	10 V/m	0,09	0,09	0,069	0,72
5	30 V/m	0,062	0,063	0,047	0,51
X	(harsh)	Case-by-case according to the situation			

NOTE Medical implant devices are not included. An absolute gain of each antenna connecting with the item is assumed to be 2,14 dBi maximum. The fields are also calculated from Formula (B.4) in Annex B.

[a] Transmitting power is converted from the electric field strength 0,2 V/m at the distance of 3 m by using Formula (B.4) in the near-field condition as 11,5 mW. Each separation distance for each field-strength is calculated using the transmitting power using also Formula (B.4).

Table 26 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Digital-television broadcast (VHF)

Disturbance degree and corres-ponding field strength	**Phenomena (sources)**				
	Digital TV broadcast P = 100 kW$_{ERP}$	Digital TV broadcast P = 100 kW$_{ERP}$	Digital TV broadcast P = 325 kW$_{ERP}$	Digital TV broadcast P = 50 kW$_{ERP}$(SW)	Digital TV broadcast P = 10 kW$_{ERP}$(DE)
	Countries				
	US [a], CA [a], BR [b]	US [a], CA [a], BR [b]	US [a], CA [a], BR [b], NL [c]	AU [c], FR [c], FI [c], DK [c], SW [c], IT [c]	PT [c], IE [c], DE [c], NO [c]
	Transmitter frequencies [MHz]				
	54 to 72	76 to 88	174 to 216	174 to 230	174 to 202/209/239/240
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	180	180	330	130	58
2 1 V/m	55	55	99	38	17
3 3 V/m	18	18	33	13	5,8
4 10 V/m	5,4	5,4	9,9	3,9	17,3
5 30 V/m	1,7	1,7	3,2	1,3	5,8
6 100 V/m	0,66	0,56	0,96	0,33	1,73
X (harsh)	Case-by-case according to the situation				

NOTE For instance, the case where a set of transmitting antennas is installed in a broadcasting tower. The antenna installation height of the transmitting antenna is assumed to be about 300 m. The fields are also calculated from Formula (B.4) in Annex B. A directivity of –30° elevation is –30 dB smaller than that of the maximum value. The attenuation includes an attenuation caused by the cross-polarization and the radiation pattern of the transmitting antenna. For example, although the electric field is 100 V/m at the point located on the boresight, the field at the observation point is 3,16 V/m.

[a] Transmission scheme of DTV: ATSC (Advanced Television Systems Committee)

[b] Transmission scheme of DTV: ISDB-T (Integrated Services Digital Broadcasting – Terrestrial)

[c] Transmission scheme of DTV: DVB-T (Digital Video Broadcasting – Terrestrial)

Table 27 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Digital-television broadcast (UHF)

Disturbance degree and corres-ponding field strength	Phenomena (sources)				
	Digital TV broadcast *P* = 48 kW$_{ERP}$	Digital TV broadcast *P* = 5 kW$_{ERP}$	Digital TV broadcast *P* = 50 kW$_{ERP}$(FI)	Digital TV broadcast *P* = 120 kW$_{ERP}$(DE)	Digital TV broadcast *P* = 1 000 kW$_{ERP}$
	Countries				
	JP [b]	KR [a] HK	FR [c], FI [c], IT [c]	IE [c], ES [c], PT [c], DE [c], DK [c], NL [c], SW [c], NO [c]	US [a], CA [a]
	Transmitter frequencies [MHz]				
	470 to 710	470 to 752/806	470 to 830/790/854	470 to 862	470 to 608, 614 to 698
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	128	41	129	200	577
2 1 V/m	38	12	39	60	174
3 3 V/m	12,7	4,1	12,9	20	57,7
4 10 V/m	3,8	1,2	3,9	6	17,3
5 30 V/m	1,26	0,4	1,3	2	5,8
6 100 V/m	0,37	0,11	0,38	0,59	1,73
X (harsh)	Case-by-case according to the situation				

NOTE For instance, the case where a set of transmitting antennas is installed in a broadcasting tower. The antenna installation height of the transmitting antenna is assumed to be about 300 m. The fields are also calculated from Formula (B.4) in Annex B. A directivity of –30° elevation is –30 dB smaller than that of the maximum value. The attenuation includes an attenuation caused by the cross-polarization and the radiation pattern of the transmitting antenna. For example, although the electric field is 100 V/m at the point located on the boresight, the field at the observation point is 3,16 V/m.

[a] Transmission scheme of DTV: ATSC (Advanced Television Systems Committee)

[b] Transmission scheme of DTV: ISDB-T (Integrated Services Digital Broadcasting – Terrestrial)

[c] Transmission scheme of DTV: DVB-T (Digital Video Broadcasting – Terrestrial)

Table 28 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Digital-television broadcast (UHF) (continued)

Disturbance degree and corres-ponding field strength	Phenomena (sources)				
	Digital TV broadcast P = 48 kW_{ERP}	Digital TV broadcast P = 5 kW_{ERP}	Digital TV broadcast P = 50 kW_{ERP}(FI)	Digital TV broadcast P = 120 kW_{ERP}(DE)	Digital TV broadcast P = 1 000 kW_{ERP}
	Countries				
	BR [b]	UK [c]	SG [c]	AU [c]	TW [c]
	Transmitter frequencies [MHz]				
	470 to 608, 614 to 806	470 to 550, 630 to 806	494 to 790	520 to 610, 750 to 806	530 to 602
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	163	258	115	258	167
2 1 V/m	49	77	35	77	50
3 3 V/m	16,4	25,8	11,5	25,8	16,7
4 10 V/m	4,9	7,7	3,4	7,7	5
5 30 V/m	1,63	2,58	1,15	2,58	1,67
6 100 V/m	0,48	0,77	0,34	0,77	0,49
X (harsh)	Case-by-case according to the situation				

NOTE 1 For instance, the case where a set of transmitting antennas is installed in a broadcasting tower. The antenna installation height of the transmitting antenna is assumed to be about 300 m. The fields are also calculated from Formula (B.4) in Annex B. A directivity of –30° elevation is –30 dB smaller than that of maximum value. The attenuation includes an attenuation caused by the cross-polarization and the radiation pattern of the transmitting antenna. For example, although the electric field is 100 V/m at the point located on the boresight, the field at the observation point is 3,16 V/m.

NOTE 2 An absolute gain of the transmitting antenna for DTV of Taiwan is assumed to be 12,25 dBi.

[a] Transmission scheme of DTV: ATSC (Advanced Television Systems Committee)

[b] Transmission scheme of DTV: ISDB-T (Integrated Services Digital Broadcasting – Terrestrial)

[c] Transmission scheme of DTV: DVB-T (Digital Video Broadcasting – Terrestrial)

The digital dividend refers to the spectrum which is released in the process of digital television transition. The digital dividend usually locates at frequency bands from 174 MHz to 230 MHz (VHF) and from 470 MHz to 862 MHz (UHF). In the case of Japan the frequency band from 90 MHz to 108 MHz (VHF low-band) also is added. Current status of the digital dividend around the world is listed below.

US: A frequency band from 698 MHz to 806 MHz is divided up into A, B, C, D, and E blocks. These frequency blocks are to be auctioned.

EU: Frequency bands of 800 MHz and 900 MHz are mainly to be allocated for 3G/4G cellular phones.

JP: Ministry of Internal Affairs and Communications sets out a policy for the division and reallocations of the frequency band. Services of ITS (intelligent transport systems) for road-to-vehicle and vehicle-to-vehicle communications, FPU (field pickup units) for broadcasting system, and radio microphones will be allowed in a frequency band from 755 MHz to 806 MHz.

Table 29 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Unlicensed radio services

Disturbance degree and corresponding field strength	Phenomena (sources)				
	Radio microphones P = 10 mW$_{ERP}$	Radio control radio service P = 0,75 W$_{EIRP}$	Family radio service (FRS) P = 0,5 W$_{ERP}$	Low power radio service (LPRS) P = 0,1 W$_{EIRP}$	Multi-use radio service (MURS) P = 2 W [a]
	Countries				
	JP	US	US	US	US
	Transmitter frequencies [MHz]				
	74,322; 806,125 to 809,75	72,75	462 to 467	216	151; 154
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	2,3	16	17	5,7	37
2 1 V/m	0,69	4,7	5	1,7	11
3 3 V/m	0,22	1,5	1,7	0,54	3,7
4 10 V/m	0,065	0,56	0,48	0,20	1,1
5 30 V/m	0,041	0,38	0,14	0,14	0,34
X (harsh)	Case-by-case according to the situation				

NOTE 1 Radio microphones, wireless telemetries, radio control radio services, citizens band radio services, personal wireless communications, cordless phones, and other short range devices are categorized in the table. However, wireless telemetries and citizens band radio services are not treated here. Some frequencies of MURS and FRS allocate for cordless phones. The fields are also calculated from Formula (B.4) in Annex B.

NOTE 2 The relationship between effective radiated power (ERP) and equivalent isotropic radiated power (EIRP) is $P_{EIRP} = 1,64 \times P_{ERP}$.

[a] 2 W is the transmitter power output; the antenna gain is 3,0 dBi.

Table 30 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Unlicensed radio services (continued)

Disturbance degree and corresponding field strength	Phenomena (sources)						
	Non-specific SRD P = 10 mW_{ERP}	Non-specific SRD P = 0,5 W_{ERP}	Alarm SRDs P = 25 mW_{ERP}	Model control SRDs E = 0,1 W_{ERP}	Wireless Audio SRDs P = 10 mW_{ERP}	PMR 446 equipment P =0,5 W_{ERP}	Digital PMR 446 equipment P = 0.5 W_{ERP}
	Countries						
	EU	EU	EU	EU	EU	EU	EU
	Transmitter frequencies [MHz]						
	40,66 to 40,7 433,05 to 434,79	868 to 870	868,6 to 869,7	34,995 to 35,225 40,665 to 40,695	863 to- 865	446,006 25 to 446,093 75	446,1 to 446,2
	Distance to source [m]						
A (controlled)	Case-by-case according to the equipment requirements						
1 0,3 V/m	2,1	16	3,6	7,2	2,3	16	16
2 1 V/m	0,96	5,0	1,1	1,9	0,7	5,0	5,0
3 3 V/m	0,66	1,7	0,37	0,98	0,23	1,7	1,7
4 10 V/m	0,45	0,5	0,098	0,66	0,063	0,48	0,48
5 30 V/m	0,32	0,16	0,046	0,47	0,04	0,14	0,14
X (harsh)	Case-by-case according to the situation						

NOTE SRD and PMR mean the short range devices and the private mobile radio, respectively. Radio microphones, wireless telemetries, radio control radio services, citizens band radio services, personal wireless communications, cordless phones, and other short range devices are categorized in the table. However, wireless telemetries and citizens band radio services are not treated here. Some frequencies of PMR and digital PMR allocate for cordless phones. The fields are also calculated from Formula (B.4) in Annex B.

The power values mentioned in Table 31 are a summary of all frequencies and the maximum allowed output power of the transmitter given as P_{PEP} (peak envelope power) of all three ITU regions. The output power used for the calculation of the distances in the table is P_{PEP} multiplied by the theoretical antenna gain of a half-wavelength dipol antenna (2,15 dB) and is given as P_{EIRP} (equivalent isotropically radiated power). Possible losses from cables, switches and mismatches are not considered to keep the model as simple as possible. The calculated field strength is only valid for the main beam of the antenna and is lower outside this beam.

The distances may vary in real situations because the typical antenna gain is different (up to 10 dB or more) and losses (e.g. from cables) have to be taken into account. These (mostly rotatable) high gain antennas are normally mounted on antenna towers 10 m to 30 m above ground or on a roof. In this case only in the direction of the main beam of the antenna the full field strength will occur. Even for slight deviations from the direction of maximum beam strength significant reductions of the antenna gain are observed.

Table 31 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Amateur radio bands above 30 MHz

Disturbance degree and corresponding field strength	Phenomena (sources)		
	Amateur radio station P = 1 500 W P_{EIRP} ≈ 2 500 W	Amateur radio station P = 1 500 W P_{EIRP} ≈ 2 500 W	Amateur radio station P = 1 500 W P_{EIRP} ≈ 2 500 W
	Transmitter frequencies [MHz]		
	50 to 54 144 to 148 219 to 220 420 to 450 902 to 928	1 240 to 1 300 2 300 to 2 450 3 300 to 3 500 5 650 to 5 925	10 000 to 10 500 24 000 to 24 250 47 000 to 47 200 75 500 to 81 500 122 250 to 123 000 134 000 to 141 000 241 000 to 250 000 >275 000
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 0,3 V/m	905	905	905
2 1 V/m	271	271	271
3 3 V/m	90,5	90,5	90,5
4 10 V/m	27,1	27,1	27,1
5 30 V/m	9,05	9,05	9,05
X (harsh)	Case-by-case according to the situation		

NOTE 1 The distances are derived assuming a power of 1 500 W and an antenna gain of 2,15 dBi of a half wavelength dipole antenna. Practical limitations restrict the antenna gain for the lower frequency bands and the amplifier power for the higher frequency bands.

NOTE 2 The above mentioned power and frequency bands are a summary of all three ITU regions. The power P is (if not otherwise mentioned) the allowed maximum output power of the amplifier. The power arriving at the antenna and radiated by it is P_{ANT} and is P reduced by the losses of the feeding cable. For easy calculation of E and d, the effective isotropic power P_{EIRP} is useful. Most antennas have a direction with maximum radiation, i.e. in that direction they have a significant antenna gain G_{ISO} compared to an isotropic radiator. E and d of this maximum radiation can be easily calculated by means of P_{EIRP}, which is obtained by multiplying P_{ANT} by the isotropic antenna gain G_{ISO}. d is the spatial distance from the antenna. A power P = 1 500 W fed into a dipole results in an isotropic effective radiated power of about P_{EIRP} ≈ 2 500 W.

In case of an amateur radio station at VHF, UHF, SHF and EHF many antenna ~~(and resulting antenna gains)~~ types are possible. Typical resulting antenna gains G_{ISO} are between about 10 dBi and > 30 dBi. These (mostly rotatable) antennas are normally mounted on antenna towers 10 m to 30 m above ground or on a roof. In this case only in the direction of the main beam of the antenna the full field strength will occur. Even for slight deviations from the direction of maximum beam strength significant reductions of the antenna gain are observed.

The same values for P_{EIRP} and therefore for E and d in the beam direction for the amateur station in this example could also be obtained with P = 100 W, a feeding cable attenuation of 2 dB and a directional antenna with an isotropic antenna gain G_{ISO} of 16 dBi. However, with the same P_{EIRP} the disturbing probability of such an antenna is much lower than that of an omnidirectional antenna, because the beam width is limited in the horizontal and vertical plane.

Table 32 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Paging service base station

Disturbance degree and corresponding field strength	Phenomena (sources)				
	POCSAG P = 250 W_{ERP}	POCSAG P = 100 W_{ERP}	ERMES P =250 W_{ERP}	FLEX™, Re FLEX™ E =1 kW_{ERP}	POCSAG P = 100 W_{ERP}
	Countries				
	JP	EU	EU	US	UK
	Transmitter frequencies [MHz]				
	276,012 5 to 283,987 5	439 to 466	169	900	138, 153, and 466
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	370	230	370	740	230
2 1 V/m	111	70	111	222	70
3 3 V/m	37	23	37	74	23
4 10 V/m	11	7	11	22	7
5 30 V/m	3,7	2,3	3,7	7,4	2,3
6 100 V/m	1,1	0,69	1,1	2,2	,69
X (harsh)	Case-by-case according to the situation				

NOTE The absolute gain of each base station antenna is 2,15 dBi, if a half wavelength dipole antenna is used for the base station. The fields are calculated from Formula (B.4) in Annex B.

Table 33 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Other RF items (1 of 6)

Disturbance degree and corresponding field strength	Phenomena (sources)				
	RTTT P= 8 W_{ERP}	Wideband data transmission systems and HIPERLANs P = 0,1 W_{ERP}	Wideband data transmission systems and HIPERLANs P = 0,2 W_{ERP}	Wideband data transmission systems and HIPERLANs P = 1 W_{ERP}	Non specific short range devices P = 0,025 W_{ERP}
	Transmitter frequencies [GHz]				
	5,795 to 5,815	2,400 to 2,483 5	5,150 to 5,350	5,470 to 5,725	2,400 to 2,483 5 5,725 to 5,875
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	66	58	83	183	3,7
2 1 V/m	20	17	24	55	1,1
3 3 V/m	6,6	5,8	8,2	18	0,74
4 10 V/m	2	1,7	2,5	5,5	0,22
5 30 V/m	0,66	0,58	0,82	1,8	0,074
X (harsh)	Case-by-case according to the situation				

NOTE The absolute gain of wideband data transmission systems/HIPERLANs is assumed to be 20 dBi maximum (for fixed wireless access service). The absolute antenna gain of RTTT and non specific short range devices is assumed to be 2,15 dBi.

Table 34 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Other RF items (2 of 6)

Disturbance degree and corresponding field strength	**Phenomena (sources)**		
	Wideband data transmission systems and HIPERLANs Terminal P = 0,1 W_{ERP}	Wideband data transmission systems and HIPERLANs Terminal P = 0,2 W_{ERP}	Wideband data transmission systems and HIPERLANs Terminal P = 1 W_{ERP}
	Transmitter frequencies [GHz]		
	2,400 to 2,483 5	5,150 to 5,350	5,470 to 5,725
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 0,3 V/m	7,4	10	23
2 1 V/m	2,2	3	7
3 3 V/m	0,74	1	2,3
4 10 V/m	0,22	0,3	0,7
5 30 V/m	0,074	0,1	0,23
X (harsh)	Case-by-case according to the situation		
NOTE The absolute gain of wideband data transmission systems/HIPERLANs is assumed to be 2,14 dBi (for terminals).			

Table 35 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, rms) and distance to source – Other RF items (3 of 6)

Disturbance degree and corresponding field strength	**Phenomena (sources)**	
	Fixed microwave services P_{EIRP} = 55 dBW (316 kW)	Vehicle-mounted field disturbance sensors (vehicle radar system) P = 60 μW/cm^2 at 3 m
	Transmitter frequencies [GHz]	
	92 to 95	46,7 to 46,9 76 to 77
	Distance to source [m]	
A (controlled)	Case-by-case according to the equipment requirements	
1 0,3 V/m	10 200	135
2 1 V/m	3 080	45
3 3 V/m	1 020	15
4 10 V/m	308	4,5
5 30 V/m	102	1,5
X (harsh)	Case-by-case according to the situation	

Table 36 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Other RF items (4 of 6)

Disturbance degree and corresponding field strength	Phenomena (sources)	
	Non specific short range devices (see ERC Recommendation 70-03) [a] P = 100 mW_{EIRP}	Road transport and traffic telematics (RTTT) [b]
	Transmitter frequencies [GHz]	
	61,0 to 61,5 122 to 123 244 to 246	63 to 64
	Distance to source [m]	
A (controlled)	Case-by-case according to the equipment requirements	
1 0,3 V/m	5,75	x
2 1 V/m	1,7	x
3 3 V/m	0,57	x
4 10 V/m	0,17	x
5 30 V/m	0,06	x
X (harsh)	Case-by-case according to the situation	

[a] No power limitations, it has to be assessed case-by-case.

[b] No power limits currently specified; however, this might change in the future.

Table 37 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – Other RF items (5 of 6)

Disturbance degree and corresponding field strength	Phenomena (sources)	
	TETRA system P = 8 W_{ERP}	UWB P = 0,11 mW_{EIRP} [b]
	Transmitter frequencies	
	380 MHz to 921 MHz [a]	3,1 GHz to 10,6 GHz, 22 GHz to 29 GHz
	Distance to source [m]	
A (controlled)	Case-by-case according to the equipment requirements	
1 0,3 V/m	66	0,25
2 1 V/m	20	0,074
3 3 V/m	6,6	0,025
4 10 V/m	2	0,007 4
5 30 V/m	0,66	0,002 5
X (harsh)	Case-by-case according to the situation	

[a] See Table B.3.

[b] In ITU-R recommendation SM 1756, the spectrum mask is specified by EIRP as -41,3 dBm/MHz. If the spectrum is assumed to be flat in the occupied bandwidth (in a case of multiband OFDM UWB, the bandwidth of a channel group is 1 584 MHz), the total power is evaluated as -9,3 dBm = 0,11 mW. An antenna gain of 0 dBi is assumed in this case.

Table 38 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, rms) and distance to source – Other RF items (6 of 6)

Disturbance degree and corresponding field strength	Phenomena (sources)		
	Road transport and traffic telematics (RTTT) P_{EIRP} = 55 dBm (PK) [a] P_{EIRP} = 50 dBm (AV) P_{EIRP} = 23,5 dBm (AV) [b]	Field disturbance sensors, incl. vehicle radar systems P = 500 mW$_{PEP}$ [c]	Non specific equipment, indoor use only P = 500 mW$_{PEP}$ [c]
	Transmitter frequencies [GHz]		
	76 to 77	57 to 64	92 to 95
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 0,3 V/m	324	129	129
2 1 V/m	97	38,5	38,5
3 3 V/m	32,4	12,9	12,9
4 10 V/m	9,7	3,85	3,85
5 30 V/m	3,24	1,29	1,29
X (harsh)	Case-by-case according to the situation		

[a] Calculation done with 55 dBm.

[b] Pulse radar only.

[c] Calculation done for 20 dBi antenna gain.

6.2.3.3 Radio frequency identification (RFID) systems

Radio frequency identification (RFID) is a contactless identification technology. It operates by generation and propagation of electromagnetic waves. The purpose of an RFID system is to enable data to be transmitted by a transponder, which is read by an RFID reader and processed according to the needs of a particular application. There are three main components of an RFID: an antenna, a transceiver and a transponder. The antenna enables communication between the transponder and the transceiver. RFID is extensively used in tracking and access applications and can work in ranges exceeding 30 m depending on the frequency and type of transponder used.

RFID systems can be classified in accordance with their frequency of operation, however the frequency of use of an RFID system is restricted to the industrial, scientific and medical (ISM) and short range devices (SRD) frequency bands. RFID systems operate by a variety of coupling methods but the most common methods are inductive coupling for low frequency (LF) RFID systems and backscatter coupling for ultra high frequency (UHF) and super high frequency (SHF) RFID systems. RFID systems can also be classified based on how the transponder is powered: passive RFID systems rely on the RF energy transferred from the transceiver to the transponder to power the transponder, whereas active RFID systems use an internal power source (usually a battery) within the transponder to continuously power the transponder and its RF communication circuitry. Table B.7 summarises the RFID technology.

Table 39 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in V/m, r.m.s.) and distance to source – RFID and railway transponder systems

Disturbance degree and corresponding field strength		Phenomena (sources)						
		RFID [a] P = 1 W	RFID [b] P = 4 W	Railway transponder system P = 20 W	RFID [c] P = 10 mW$_{ERP}$	RFID [d] P = 1 W (antenna gain = 6 dBi)	RFID [e] P = 4 W$_{EIRP}$	RFID P = 4 W$_{EIRP}$
		Transmitter frequencies [MHz]						
		Below 0,135	13,56	27	433	860 to 960	2 450	5 875
		Distance to source [m]						
A	(controlled)	Case-by-case according to the equipment requirements						
1	0,3 V/m	0,2	3,3	20	2,3	36	36,55	36,55
2	1 V/m	0,11	1,6	6	0,69	11	11	11
3	3 V/m	0,062	0,9	2,5	0,21	3,6	3,7	3,7
4	10 V/m	0,035	0,49	1,1	0,091	1,1	1,1	1,1
5	30 V/m	0,02	0,28	0,62	0,063	0,36	0,37	0,37
X	(harsh)	Case-by-case according to the situation						

NOTE 1 There may be different frequencies used for services such as RFID in different countries. A corresponding evaluation of the field strengths to be expected can be done according to the Formulae (B.6) and (B.7) (for further information on the frequency bands used see www.ero.dk).

NOTE 2 The fields are calculated from Formula (B.6) in Annex B in the cases of 135 kHz and 13,56 MHz RFID, and railway transponder systems. The fields are calculated from Formula (B.4) in Annex B in the cases of the other systems. The loop current is given by the input power into the loop antenna of an RFID reader. When the impedance of the loop antenna is matched to that of the driver circuit of the RFID (usually Z_0 = 50 Ω), the loop current, I, is obtained as $I = (P/ Z_0)0,5$. The values of the current are 0,14 A, 0,28 A, and 0,63 A in the case of 135 kHz and 13,56 MHz RFID, and railway transponder systems, respectively. The loop area, S, as shown in Annex B is assumed as 1 m^2.

[a] See ISO/IEC 18000-2.

[b] See ISO/IEC 18000-3.

[c] See ISO/IEC 18000-7.

[d] See ISO/IEC 18000-6.

[e] See ISO/IEC 18000-4; the power level is specified by EIRP, an antenna gain of 0 dBi is assumed.

The disturbance degrees in near-field magnetic-fields are expressed in Table 40.

Table 40 – Disturbance degrees, levels ~~for modulated radiation disturbances~~ (in µA/m, r.m.s.) and distance to source – RFID and railway transponder systems

Disturbance degree and corresponding field strength	Phenomena (sources)		
	RFID [a] P = 1 W_{ERP}	RFID [b] P = 4 W_{ERP}	Railway transponder system P = 20 W_{ERP}
	Transmitter frequencies [MHz]		
	Below 0,135	13,56	27
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 3 µA/m	16	600	5 300
2 10 µA/m	10	180	1 600
3 30 µA/m	7,2	60	530
4 100 µA/m	4,8	17	160
5 300 µA/m	3,3	5,2	53
6 1000 µA/m	2,2	2,7	16
X (harsh)	Case-by-case according to the situation		

NOTE The fields are calculated from Formula (B.7) in Annex B. The loop current is defined by the input power into the loop antenna of an RFID reader. When the impedance of the loop antenna is matched to that of the driver circuit of the RFID (usually Z_0 = 50 Ω), the loop current I, is obtained as $I = (P/ Z_0)/2$. The values of the current are 0,14 A, 0,28 A and 0,63 A in the case of 135 kHz, 13,56 MHz and 27 MHz, respectively. The loop area S, as shown in Annex B, is assumed as 1 m^2.

[a] See ISO/IEC 18000-2.

[b] See ISO/IEC 18000-3.

6.2.3.4 Magnetic fields from 9 kHz to 150 kHz

Magnetic fields are also generated by sources operating at frequencies other than power frequencies (or harmonics of power frequencies). The most typical application of such intentionally generated magnetic fields is in short range communication systems. Other applications include induction heating.

For intentional radiators, the items tend to be short range communication systems of unidirectional and bidirectional capability. In general, these systems are characterised by a transponder system and a base station both of which comprise an inductive loop. Depending on the system and application, the transponder could be passive, a term used to describe the fact that the transponder does not contain a power source but obtains its operating power via magnetic coupling between the base station and the transponder, or active where the transponder has an integrated power source.

Short range communication systems are used extensively for supply chain management applications as well as in animal husbandry, retail security (i.e. RFID applications, see 6.2.3.3) and railway signalling systems to name a few. Typical frequencies of operation are 29 kHz, 30 kHz, 36 kHz, 43 kHz, 56 kHz, 125 kHz and 134,2 kHz.

For these items the radiated magnetic field is a function of the loop area and EIRP. Typical values of magnetic fields from such systems are given in Table 40.

6.2.4 Radiated pulsed disturbances

Pulsed (transient) radiated disturbances of interest are those which might, despite a short duration, have an influence on the item because of their important instantaneous rate of rise.

In fact, real pulses exhibit very complicated waveforms, which sometimes are only partially known because of the limited bandwidth of measurement tools.

The values encountered in practice strongly depend on the distance between victim and source (see Annex B for more information). Because the phenomenon involves coupling of a field into the equipment circuits, the derivative, or rate of rise of the pulse, and the front duration are the significant attributes of the phenomenon. Hence no specific distances can be given in Table 41.

For the purpose of this document, pulsed radiated disturbances are the radiated disturbances which do not last for more than 200 ms, and which do not change polarity more than 10 times for their duration (further information is given in Annex D).

Table 41 – Disturbance degrees, levels (in rate of rise) and distance to source – Radiated pulsed disturbances

Disturbance degree and corresponding rate of rise	**Phenomena (sources)**			
	Open field Lightning strike to ground [a, b]	Gas-insulated substations Disconnect switch [c]	Air-insulated substations Disconnect switch [c]	Below overhead lines conducting lightning surges and switching operations [c]
	Rise time [ns]			
	100 to 500	10	100	1 000
	Distance to source [m]			
A (controlled)	Case-by-case according to the equipment requirements			
~~1~~	~~30 V m^-1 ns^-1~~ ~~d m~~	~~100~~ ~~d~~	~~30~~ ~~d~~	~~3~~ ~~d~~
~~2~~	~~100~~ ~~d~~	~~300~~ ~~d~~	~~100~~ ~~d~~	~~10~~ ~~d~~
~~3~~	~~300~~ ~~d~~	~~1 000~~ ~~d~~	~~300~~ ~~d~~	~~30~~ ~~d~~
~~4~~	~~1 000~~ ~~d~~	~~3 000~~ ~~d~~	~~1 000~~ ~~d~~	~~100~~ ~~d~~
~~5~~	~~3 000~~ ~~d~~	~~10 000~~ ~~d~~	~~3 000~~ ~~d~~	~~300~~ ~~d~~
1 30 V m^{-1} ns^{-1}	d	d	d	d
2 100 V m^{-1} ns^{-1}	d	d	d	d
3 300 V m^{-1} ns^{-1}	d	d	d	d
4 1000 V m^{-1} ns^{-1}	d	d	d	d
5 3000 V m^{-1} ns^{-1}	d	d	d	d
X (harsh)	Case-by-case according to the situation			

NOTE These phenomena involve the coupling of a field into the equipment circuits. Therefore the derivative, or rate of rise of the pulse, and the front duration are the significant attributes of the phenomenon. For this reason, no specific disturbance distances can be given here.

[a] At a distance d greater than about 30 m.

[b] The amplitude of the disturbance degree depends on the distance and the steepness of the lightning strike. The shielding offered by metallic structures, buildings and terrain profile can be expected to be effective in reducing the amplitude.

[c] The amplitude of the disturbance is very much dependent on the distance from the source. It also depends on the amplitude of the source phenomenon, which is roughly proportional to the operating voltage of the system. This fact is generally compensated by the need to keep, for insulation requirements, greater distances from sources operating at higher voltages. The latter situation does not apply to gas-insulated substations.

Table 42 – Disturbance degrees, levels ~~for pulsed radiation disturbances~~ (in V/m, Pk) and distance to source – RADAR systems

Disturbance degree and corresponding field strength	Phenomena (sources)		
	Ground traffic control (police) 500 mW ($EIRP_{Pk}$)	Ground traffic control (airport) 30 kW ($EIRP_{Pk}$)	Car-mounted RADAR (adaptive cruise control) 316 W ($EIRP_{Pk}$) [a]
	Transmitter frequency [GHz]		
	24,125	9,1	77
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 0,3 V/m	40,7	3 160	324
2 1 V/m	12,2	948	97,0
3 3 V/m	4,07	316	32,4
4 10 V/m	1,22	94,8	9,70
5 30 V/m	0,41	31,6	3,24
X (harsh)	Case-by-case according to the situation		

NOTE The RADAR systems in this table are examples of systems which can be found in traffic areas or airports. In some situations higher levels or other frequencies ~~have to be taken in account~~ can occur.

[a] The power level (of 316 W $EIRP_{Pk}$) used for the calculation is the maximum level allowed according to EN 301 091 V1.1.1 for this type of RADAR systems. The power level of actual systems in use is much lower (approx. 10 W $EIRP_{Pk}$).

7 Electrostatic discharge

7.1 General

Electrostatic discharge (ESD) occurs as a result of a charged person or object approaching another person or object. The ESD receptor is first subjected to the electric field associated with the charge, then, when dielectric breakdown occurs, there is a discharge with transient current of a complex nature that gives rise to a transient electromagnetic field. The ESD phenomenon is strongly dependent on ambient humidity, temperature, nature of surrounding dielectrics, etc.

7.2 ESD currents

Table 43 shows the values of the rate of current rise associated with the air discharge, the significant attribute in producing disturbing fields. This table also shows the charge voltage before discharge, a significant attribute in the potential for energy exchange, as well as current amplitude.

There is no strict correlation between the values of charge voltage and the rates of rise of current given in Table 43, because other characteristics of the ESD event can influence the outcome.

Table 43 – Disturbance degrees and levels for pulsed disturbances (rate of rise) caused by ESD

Disturbance degrees	Phenomena (sources)			
	Slow ESD		Fast ESD	
	Rise time: 5 ns Duration: 15 ns Rate of occurrence: Single Frequency of occurrence: [a] Source: 100 Ω to 500 Ω [b] 100 pF to 500 pF [c]		Rise time: 0,3 ns Duration: 2 ns Rate of occurrence: Single Frequency of occurrence: [a] Source: 100 Ω to 500 Ω [b] 100 pF to 500 pF [c]	
	Significant attribute			
	(A/ns)	(kV)	(A/ns)	(kV)
A (controlled)	Case-by-case according to the equipment requirements			
1	-	-	-	<1
2	25	-	25	2
3	40	-	40	4
4	80	8	80	8
5	100	15	-	-
6	-	30	-	-
X (harsh)	Case-by-case according to situation			

[a] Depends on the number of persons in the area.

[b] Depends on the source: hand tool, bare hand, furniture.

[c] Depends on an individual's isolation or size of furniture at the instance of the discharging process.

7.3 Fields produced by ESD currents

Table 44 shows the values of transient electric and magnetic fields gradients external to the receptor, measured at a distance of 0,1 m from the discharge. See Annex C for further information.

Table 44 – Disturbance degrees and levels for radiated field gradients caused by ESD

Disturbance degrees	Level of radiated field gradients	
	$V\ m^{-1}\ ns^{-1}$	$A\ m^{-1}\ ns^{-1}$
A (controlled)	Case-by-case according to the equipment requirements	
1	2 000	5
2	4 000	10
3	8 000	20
4	16 000	40
X (harsh)	Case-by-case according to the situation	

8 Classification of environments

8.1 General

In general, the electromagnetic environment at a given location is determined by the combination of the naturally-occurring and man-made electromagnetic phenomena present and the disturbance level at which each phenomenon occurs.

The electromagnetic environment is not the same at all locations, since the electromagnetic phenomena described in Clauses 5, 6 and 7 do not all occur at every location, nor do those phenomena present always occur with the same disturbance level. Since the majority of the phenomena described in Clauses 5, 6 and 7 are man-made, the existence of a given phenomenon and its associated disturbance level at a given location generally depends upon factors that include: the types and numbers of electrical and electronic equipment (including radio transmitting equipment) operated at and nearby the location.

For the purpose of simplicity, it is useful to describe a minimal set of location classes that contain the phenomena and associated disturbance levels that are typical of a large number of locations. This document defines a minimal set of archetypical location classes. The background to this selection is presented in 8.2, and 8.3 to 8.5 describe each archetype location class.

8.2 Location classes

Patterns of land use are noted to vary significantly between different regions of the world. The observed differences are due largely to the combination of geographical, historical and cultural differences towards the concept of land use regulation and its enforcement through local legal frameworks.

One extreme pattern of land use is observed within those population centres that have developed with the concept of land use regulation (and its associated enforcement through local legal frameworks) adopted from the very outset. In this instance, the population centres are divided into a number of functionally distinct, clearly delineated, separate sections (often referred to as 'zones'). A change in land use occurs relatively infrequently, due to the time taken to engage with the relevant process embodied within the local legal framework.

The opposite extreme in the pattern of land use is observed within population centres that have developed without any application of the concept of land use regulation. In this instance, there is no division of the centre into functionally distinct, clearly delineated, separate sections; rather the centres are characterised by a largely ad hoc land use, with many diverse functions being performed within the same area. In such a location, changes in land use occur relatively frequently, again in a largely ad hoc manner.

Many other patterns of land use are observed across the different regions of the world that fall somewhere between these two extremes.

Land use regulation controls the activities that may take place at a given location. For the purposes of this document, it therefore similarly controls the types of electrical and electronic equipment (including radio transmitting equipment) that are likely to be situated at a given location and in doing so influences the types and severity of the electromagnetic phenomena present in the electromagnetic environment at a given location.

Within this document, three archetypal land uses, location classes and hence electromagnetic environments are recognised, these being:

– residential;
– commercial/public;
– industrial.

In practice, the actual electromagnetic environment at a given location can be thought of as the weighted combination of the three archetypes. This concept is displayed on Figure 7.

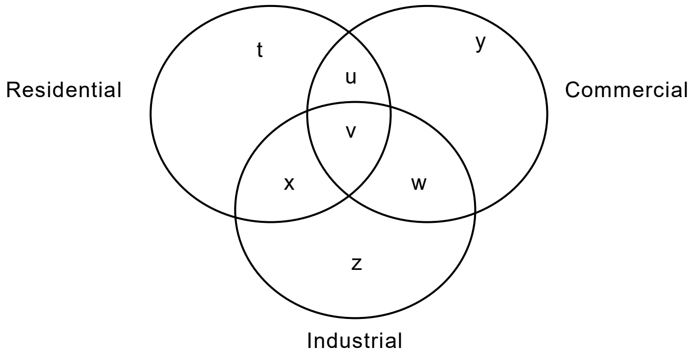


Figure 7 – Concept of location classes

Note that Figure 7 can be interpreted in two ways:

1) As a spatial diagram, indicating the environments created due to the specification and delineation of separate areas as residential, commercial and industrial.

   Any location in the centres of these separate areas will therefore experience the archetypical electromagnetic environments (areas t, y and z on Figure 7). However, locations at the boundary or boundaries between these separated areas (areas u, v, w and x on Figure 7) will experience an electromagnetic environment that is a blend of the archetypical environments, containing phenomena from the adjacent archetypes.

2) As a functional diagram, demonstrating how changes in the activities performed in a designated area (i.e. the area 'function') can lead to the location's environment deviating from the archetype through the introduction of electrical or electronic equipment (and hence of phenomena or a severity of phenomena) not associated with the archetype. Examples include:

   – The location and operation of a single/small number of ISM items within a residential area (e.g. a community health centre located within a residential area). In this instance the residential electromagnetic archetype is perturbed by the electromagnetic phenomena associated with the operation of ISM equipment. This gives rise to area x of Figure 7.

   – The location and operation of a single item of industrial machinery within a commercial area to provide a specific service (e.g. a car wash located near ~~to/~~or within a public retail area). In this instance, the commercial electromagnetic environment is perturbed by the electromagnetic phenomena associated with the operation of the industrial machinery. This gives rise to area w of Figure 7.

   – The entirely ad hoc location of electrical and electronic equipment at a given area with undesignated land use (e.g. the Developing World scenario described earlier). In this instance, the electromagnetic environment will contain phenomena and severity levels associated with all three archetypes. This gives rise to area v of Figure 7.

   – The location and operation of telecommunications, office and IT equipment ~~nature of SOHO (definition: Small Office/Home Office) activity~~ means that low levels of administrative/service industry activity may be performed within domestic premises (i.e. home offices) rather than in commercial premises (i.e. small offices). This gives rise to area u of Figure 7.

It is noted that area z of Figure 7 can also be applied to roads and railways: by their very nature, roads and railways pass either by or through all areas of designated land use (often being the boundary between the separated areas of designated land use) and hence experience phenomena and a severity of phenomena from each archetype. The range and severity of phenomena will vary from location to location, depending upon the adjacent land use. These phenomena are in addition to any intrinsic phenomena associated with the road and railways: for example, the railways will have phenomena associated with signalling systems and the use of large electrical traction systems.

It is on this basis that 8.3 to 8.5 describe the essential properties of the three archetypes.

8.3 Residential location class

8.3.1 Description of residential locations

In accordance with Figure 7, the residential location exists in an area of land designated for the construction of domestic dwellings. The function of a domestic dwelling is to provide a place for one or more people to live.

The domestic dwelling delivers a number of functions that may employ electrical or electronic equipment. These functions include:

– the provision of either heating or cooling (depending upon the prevailing environment);
– the provision of light;
– the provision of hot water for the purposes of maintaining personal hygiene.

The domestic dwelling also supports a number of activities that may employ electrical or electronic equipment. Such activities include:

- the storage and preparation of food;
- the cleaning and drying of clothing;
- the operation of IT equipment;
- the consumption of broadcast or streamed entertainment services.

A dwelling can be a single, separate building (as in a detached house) or a separate section of a larger building (as in an apartment in an apartment block).

Subclause 8.3 considers the electromagnetic environment within a domestic dwelling. The approach taken is to treat the individual dwelling as an item of electrical or electronic equipment. This allows the dwelling to have the standard IEC ports.

8.3.2 Equipment typical to the residential location

Any equipment within the residential location is connected to the internal low-voltage power supply network via either transformer-based or switched mode power supplies.

The residential location is characterised by the ad hoc location of electrical and electronic equipment performed by the residents. Equipment items can therefore be placed very near to/ or in contact with one another in certain high density locations. These locations include:

– the home office desk, with PC located on/below the desk; VDU, speakers, printer, wireless keyboard and wireless mouse located on the desktop; portable telephone handset and/or cellular telephone handset located on the desktop, near to or in physical contact with one of the items;
– the 'adolescent's bedroom', that may contain the above described home office desk in addition to a TV set with DVD/VCR and games console.

High density locations typically access the internal low-voltage power supply network via a single outlet socket that is fitted with a distribution board/power strip.

A non-exhaustive list of the types of equipment present and operated within the residential location is presented in Table 45. The equipment has been categorised according to function.

Table 45 – Examples of equipment present in the residential location class

Equipment Function	Examples
Food preparation/storage	Storage: Refrigeration and/or freezing Preparation: Microwave oven, electric oven, electric hob, electric induction heating, gas oven, gas hob with electrostatic ignition Preparation: Toaster, water kettle, rice cooker, steamer, bread-maker, ice-cream maker, waffle iron, sandwich toaster, food processor, steamer, deep fat fryer
Environmental	Lighting: Fluorescent lighting, dimmer switches, LV transformers – halogen lamps Heating: Central heating system and electronic controller
Cleaning	Washing machine, ~~Drying Machine~~ dryer (separate or integrated), vacuum cleaner, floor polisher, dishwasher
HVAC and sanitation	Power shower, electronic toilet, stair lift, tanning booth, electric blanket, medical equipment
Entertainment	TV broadcast receiver (terrestrial – analogue + digital) Radio broadcast receiver (terrestrial – analogue + digital) VCR/DVD/personal or digital video recorder (PVR or DVR) Associated equipment – surround sound speakers & amplifiers Hi Fi (networked and non-networked) Games consoles (networked and non-networked) Electronic toys/cybertoys Remote controlled toys
IT	PC Wireless mouse/keyboards Home network equipment Home gateway, wireline/wireless items, PLT
Security	Cameras/camera networks Wireless gate/garage locks

8.3.3 Boundaries relevant for equipment operated at residential locations

The domestic dwelling has the following separate wireline infrastructure:

– low-voltage power supply distribution network;
– telephony extension wiring;
– coaxial distribution network.

Hence conducted environments are required for each infrastructure.

Some dwellings are supplied by their own generator.

The domestic dwelling can possess the following internal infrastructure:

- low-voltage power supply distribution network;
- telephony extension wiring;
- coaxial distribution network;
- LAN cabling;
- water distribution network;

- room lighting units;
- heating/ventilation/air-conditioning units.

Internal infrastructure may be installed either during the construction of the dwelling or subsequently during a refit/remodelling exercise.

The enclosure port of the dwelling is therefore the dwelling boundary. When the dwelling consists of a single, separate building (as in a detached house) the enclosure port is the outer walls of the building. When the dwelling is a separate section of a larger building (as in an apartment in an apartment block), the enclosure port is the boundary (walls, ceiling and floor) to the dwelling.

8.3.4 Interfaces and ports to residential locations

The domestic dwelling can possess a number of external ports that connect internal infrastructure with external infrastructure as listed in the following antenna ports.

Reception antennas:

- internal coaxial distribution network that is connected to an external VHF broadcast radio reception antenna;
- internal coaxial distribution network that is connected to an external UHF terrestrial broadcast TV reception antenna;
- internal coaxial distribution network that is connected to an external coaxial distribution network and ultimately (an) external CATV broadcast reception antenna(s);
- internal coaxial distribution network that is connected to an external SHF satellite broadcast TV reception antenna;
- internal coaxial distribution network that is connected to an external xHF broadcast radio reception antenna.

Broadcast antennas:

- internal coaxial distribution network that is connected to an external licensed amateur radio antenna;
- internal coaxial distribution network that is connected to an external licensed citizen's band (CB) antenna;
- internal coaxial distribution network that is connected to an external satellite-based internet access.

Power ports:

- internal low-voltage power supply distribution wiring that is connected to an external low-voltage AC power distribution network.

Signal ports:

- internal telephony extension wiring that is connected to an external wireline telecommunications network;
- internal coaxial distribution network that is connected to an external cable TV distribution network.

8.3.5 Attributes of residential locations

In addition to the more or less general characterization of residential locations attributes can be used to conclude more quantitatively on the compatibility levels present at a residential location. Table 46 gives a list of attributes applicable to the residential location class.

Table 46 – Attributes of the residential location class

Ports	Attributes	General
	External environment [a]	
Enclosure	Amateur radio further than 100 m [b]	X
	CB radio further than 20 m [b]	X
	Broadcast transmitter operating below 1,6 MHz further than 5 km [b]	X
	FM and TV transmitters further than 1 km [b]	X
	Cellular communication systems with remote base station further than 200 m (hand-held transceivers, e.g. GSM, WiMAX etc.) [b]	X
	Paging systems, base stations, further than 1 km [b]	X
	Aviation RADAR further than 5 km [b]	X
AC power	Feeding MV- or HV-line further than 20 m [b]	X
Signal	Telecommunication line [c]	X
	Cable TV [d]	X
	Internal environment [e]	
Enclosure	Cellular communication systems with external base station (hand-held transceivers, e.g. GSM, etc.)[f]	X
	Portable communication systems with internal base-station (hand-held transceivers, mobile phones i.e. CT, CT2, DECT, Bluetooth, Wi-Fi etc) [g]	X
	High concentration of multimedia and household equipment	X
	Presence of microwave oven up to 1,5 kW	X
	Presence of medical equipment (Group 2 according to CISPR 11) further than 20 m [b]	X
	Proximity to MV/LV substations further than 20 m [b]	X
	Proximity to arc welders (mobile) further than 20 m [b]	X
	Proximity to HV substations further than 100 m [b]	X
AC power	AC cabling LV	X
	High concentration of switched mode power supplies	X
	Existence of PLT equipment	X
Signal	Lines < 30 m [h]	X
	Lightning exposure	X

a	This portion of the table presents contributors to the electromagnetic environment within a location class that are located ~~external to~~ outside the location.
b	If the stated separation is fulfilled, the radiated field strength will not exceed the compatibility level given in Table A.1, otherwise the compatibility level needs to be adjusted.
c	This assumes a UTP connection from the PSTN.
d	This assumes a coaxial cable entering the location.
e	This portion of the table presents contributors to the electromagnetic environment within a location class that are located ~~internal to~~ inside the location.
f	This deals with the radiated signal from the handheld transceivers located within the location class.
g	This deals with the radiated signal from both: the handheld transceivers and the base stations located within the location class.
h	This includes: Ethernet, security systems.

8.4 Commercial/public location class

8.4.1 Description of commercial/public locations

Commercial/public location is defined as the environment in areas of the centre of a city, offices, public transport systems (road/train/underground), and modern business centres containing a concentration of office automation equipment (PCs, fax machines, photocopiers, telephones, etc.). The following areas correspond to this environment:

– retail outlets, for example shops, supermarkets;

– business premises, for example offices, banks, data centres (server farms);

– area of public entertainment, for example cinemas, public bars, dance halls;

– places of worship (e.g. temples, churches, mosques, synagogues);

– outdoor locations, for example petrol stations, car parks, amusement and sports centres.

8.4.2 Equipment and interference sources existent in commercial/public locations

Commercial/public locations are characterised by a high density of varying items of equipment installed and brought in by the public. Generally, the items of equipment provide a service for many users and can be operated simultaneously, and some of these might act as an adverse interference source. The electromagnetic environment in commercial/public locations is not constant but varies as a function of time depending on the functional use of the installation. A non-exhaustive list of equipment typically operated in a commercial/public location is given as follows:

– information technology equipment: a variety of fixed and mobile information technology equipment including but not limited to: mobile communication items, video information display systems, public address systems, audio frequency inductive loops, general IT equipment, POS terminals, audio frequency information systems (i.e. help points);

– transportation equipment: trams, buses, cars;

– lifts and escalators;

– power equipment: low and medium-voltage power equipment, power generators, UPS.

8.4.3 Boundaries relevant for equipment operated at commercial/public locations

There are several types of boundaries that should be considered for equipment used in commercial locations.

Boundaries of the commercial/public location with respect to the external environment:

– separation by spatial conditions such as fences, walls, or partitions;

– separation by electrical conditions by the substations that connect the commercial/public network to the other network;

– separation by organizational conditions that control access to the location of the installation.

The disturbances at those boundaries make up one part of the total electromagnetic environment to which an item of equipment is exposed at a commercial/public location.

The other part of the resultant electromagnetic environment is made up by the items of equipment in the location itself. The operation of those items of equipment causes electromagnetic disturbances forming a total disturbance level in the installation. The levels of disturbances as well as their characteristics might be affected by the placement of equipment and its installation conditions.

Boundaries of the commercial/public location with respect to the internal environment are as follows:

- separation by different power supplies;
- deliberate spatial separation of items of equipment;
- deliberate spatial separation of connection lines.

8.4.4 Interfaces and ports to commercial/public locations

At commercial/public location boundaries there exists interfaces/ports through which electromagnetic phenomena may propagate. In case of an enclosure port such propagation consists of radiated electromagnetic fields whereas in the case of an AC port the propagation consists of electromagnetic conducted disturbances.

Commercial/public locations share boundaries with other such locations as well as with residential and industrial locations. The interfaces shared with these external environments are:

– enclosure
– AC port
– DC port
– signal port (including telecommunication port)

There are ~~equally~~ also interfaces with equipment installed within the same commercial/public location. Such interface ports include:

- enclosure
- AC port
- DC port
- signal port (including telecommunication port)
- earth port (including both, functional and safety earth port)

8.4.5 Attributes of commercial/public locations

In addition to the more or less general characterization of commercial/public locations, attributes can be used to conclude more quantitatively on the compatibility levels present at a commercial/public location. Table 47 gives a list of attributes applicable to the commercial/public location class. The description by means of attributes further allows to take into account specific aspects of various locations of the commercial/public location class. The following table gives a list of attributes applicable to

– commercial locations;
– general public locations (park, amusement facilities, public offices, etc);
– public hospitals, educational institutions (school, university, college, etc);

– public traffic areas, railway stations, and airports.

The difference in these locations of the commercial/public location class refers mostly to one or two electromagnetic phenomena only. Hence a specific commercial/public location can essentially be described by the attributes of the commercial/public general type with a modification referring to some specific electromagnetic phenomena which are more or less distinct in the specific commercial/public location.

Table 47 – Attributes of various types of the commercial/public location class

Ports	Attributes	Commercial	Public/General	Public/Hospital	Public/Traffic
	External environment [a]				
Enclosure	Amateur radio further than 20 m [b]	X	X	X	X
	CB radio further than 20 m [b]	X	X	X	
	CB radio between 5 and 20 m				X
	Broadcast transmitter operating below 1,6 MHz further than 5 km [b]	X	X	X	X
	FM and TV transmitters further than 1 km [b]	X	X	X	X
	Cellular communication systems with remote base station further than 200 m (hand-held transceivers, e.g. GSM, WiMAX etc.) [b]	X	X		
AC power	Feeding MV- or HV-line [b]			X	X
Signal	Telecommunication line [c]	X	X	X	X
	Internal environment [d]				
Enclosure	Paging systems [f]	X	X	X	X
	Portable communication systems (hand-held transmitters, mobile phones) [e, f]	X	X	X	X
	Limited/controlled use of portable communication systems [b]			X	X
	High concentration of ISM equipment (Group 1 according to CISPR 11) [b]			X	
	Proximity to low-power ISM equipment (Group 2 according to CISPR 11), typically less than 1 kW [b]	X	X	X	X
	Proximity to high-power ISM equipment (Group 2 according to CISPR 11), typically more than 1 kW [b]			X	
	Proximity to LV and MV substations closer than 20 m [b]			X	X
	Proximity to HV substations closer than 20 m [b]				X
	Proximity of medium-voltage and high-voltage lines closer than 20 m [b]		X	X	X
	Proximity to arc welders (mobile) [b]				X
	Proximity to arc welders closer than 20 m [b]				

AC power	AC cabling LV [b]	X	X	X	X
	AC cabling MV [b]			X	X
	AC bus bar systems [b]			X	X
	Large power drive systems (> 16 A per phase) [b]			X	X
	Switching of inductive or capacitive loads				X
	Possibility of high fault currents				X
	High inrush loads				X
DC power	DC distribution system			X	X
	Switching of inductive or capacitive loads				X
	High inrush loads				X
Signal	Long lines (> 30m) [g]	X	X	X	X
	Conduit runs likely	X	X	X	X
	Separation of different cable categories by distance	X	X	X	X
	Lightning exposure	X	X	X	X
	Overvoltage / lighting protection			X	X
Earth	Equipotential bonding system			X	X
	Extensive ground mats, generally well controlled			X	X
	Possibility of large ground fault currents				X

[a] This portion of the table presents contributors to the electromagnetic environment within a location class that are located ~~external to~~ outside the location.

[b] If the stated separation is fulfilled, the radiated field strength will not exceed the compatibility level given in Table A.1, otherwise the compatibility level needs to be adjusted.

[c] This assumes a UTP connection from the PSTN.

[d] This portion of the table presents contributors to the electromagnetic environment within a location class that are located ~~internal to~~ inside the location.

[e] This deals with the radiated signal from the handheld transceivers located within the location class.

[f] This deals with the radiated signal from both: the handheld transceivers and the base stations located within the location class.

[g] This includes: Ethernet, security systems.

8.5 Industrial location class

8.5.1 Description of industrial locations

Industrial locations can generally be described by the existence of an installation with one or more of the following characteristics:

– industrial and scientific equipment is operated;

– a lot of items of equipment are installed and connected together and work simultaneously;

– significant amount of electrical power is generated, transmitted and/or consumed;

– installation is supplied from a dedicated high or medium-voltage transformer;

– installation follows guidelines (e.g. installation of equipment, maintenance, operations);

– external influences are less dominant (because the disturbances are mostly produced by equipment of the industrial location itself).

The last characteristic stresses the fact that the electromagnetic environment at an industrial location is predominantly produced by the equipment and installation present at the location rather than by influences external to the industrial installation.

The above characteristics do not apply to any industrial installation in the same extent. There are types of industrial installations where some of the electromagnetic phenomena appear in a more severe degree, for example high levels of radiated electromagnetic disturbances are more likely to be expected in industrial installations where ISM equipment is operated that uses radiofrequency for treatment of material. On the other hand there are also types of industrial installations where some of the electromagnetic phenomena appear in a less severe degree, for example when installation conditions are maintained, preventing an electromagnetic phenomenon from appearing, or if it appears then only with a reduced amplitude. This situation can be expressed and described by attributes specific to various locations of the industrial location class (see 8.5.5).

Industrial locations exist ~~in case~~ for the following examples of installations: metalworking, pulp and paper, chemical plants, car production, power stations, substations.

8.5.2 Equipment and interference sources ~~existent~~ present in industrial locations

Industrial installations are characterized by the fact that many items of equipment are installed together, are operated simultaneously, and some of these items of equipment might act as a severe interference source. A non-exhaustive list of equipment typically operated in an industrial location is given as follows:

1) equipment which generates and/or uses locally radiofrequency for industrial, scientific or similar purposes
   - general: laboratory equipment, scientific equipment, semiconductor converters, industrial electro-heating equipment with operating frequencies less than or equal to 9 kHz, machine tools, industrial process measurement and control equipment, semiconductor manufacturing equipment;
   - detailed: signal generators, measuring receivers, frequency counters, flow meters, spectrum analysers, weighing machines, chemical analysis machines, electronic microscopes, switched mode power supplies and semiconductor converters, semiconductor rectifiers/inverters, resistance heating equipment with built-in semiconductor AC power controllers, arc furnaces and metal melting ovens, plasma and glow discharge heaters, X-ray diagnostic equipment, computerised tomography equipment, patient monitoring equipment, ultrasound diagnostic and therapy equipment, ultrasound washing machines, regulating controls;
2) equipment which generates and/or uses radiofrequency energy for the treatment of material, for inspection/analysis or for similar purposes
   - general: microwave-powered UV irradiating ~~apparatus~~ equipment, microwave lighting ~~apparatus~~ equipment, industrial induction heating equipment operating at frequencies above 9 kHz, induction cookers, dielectric heating equipment, industrial microwave heating equipment, electric welding equipment, electro-discharge machining (EDM) equipment;
   - detailed: metal melting, billet heating, component heating, soldering and brazing, arc welding, arc stud welding, resistance welding, spot welding, tube welding, wood gluing, plastic welding, plastic preheating, food processing, biscuit baking, food thawing, paper drying, textile treatment, adhesive curing, material preheating, short-wave diathermy equipment, microwave therapy equipment, magnetic resonance imaging (MRI), medical HF sterilizers, high frequency (HF) surgical equipment, crystal zone refining.

8.5.3 Boundaries relevant for equipment operated at industrial locations

There are several types of boundaries which are relevant to be considered for equipment used in industrial locations.

Boundaries of the industrial location with respect to the external environment:

- separation by spatial conditions such as fences or walls;
- separation by electrical conditions such as the substations which connect the industrial network to the public one;
- separation by organizational conditions such as controlled access to the location of the installation.

The disturbances at those boundaries make up one part of the total electromagnetic environment to which an item of equipment is exposed at an industrial location.

The other part of the resultant electromagnetic environment is made up by the items of equipment in the installation itself. The operation of those items of equipment causes electromagnetic disturbances to form a total disturbance level in the installation. The levels of disturbances as well as their characteristics might be affected by the placement of equipment and its installation conditions.

Boundaries of the industrial location with respect to the internal environment:

- separation by different power supplies;
- deliberate spatial separation of items of equipment;
- deliberate spatial separation of connection lines.

NOTE Defining and deliberately introducing boundaries within an industrial installation could be established by introducing a zone concept.

8.5.4 Interfaces and ports to industrial locations

At boundaries which are relevant for equipment in industrial locations there exist interfaces/ports through which electromagnetic phenomena propagate. In case of an enclosure port such propagation is done by electromagnetic fields, in case of the AC port, for example, the propagation is done by conducted phenomena (e.g. surges, harmonics).

As in the case of boundaries, there exist interfaces/ports with respect to the external environment

– enclosure
– AC port
– signal port (including telecommunication port)

and interfaces ports between items of equipment within the industrial installation

- enclosure
- AC port
- DC port
- signal port (including telecommunication port)
- earth port

8.5.5 Attributes of industrial locations

In addition to the more or less general characterization of industrial locations, attributes can be used to conclude more quantitatively on the compatibility levels present at an industrial location. Table 48 gives a list of attributes applicable to the industrial location class. The description by means of attributes further allows to take into account specific aspects of various locations of the industrial location class. Table 48 gives a list of attributes applicable to

- general industrial locations,

- heavy-industrial locations,
- process industry locations,
- power station and high-voltage substations.

The difference in those locations of the industrial location class refers mostly to one or two electromagnetic phenomena only. Hence a specific industrial location can essentially be described by the attributes of the general type with a modification referring to some specific electromagnetic phenomena which are more or less distinct in the specific industrial location.

Table 48 – Attributes of various types of the industrial location class

Ports	Attributes	General	Heavy	Process	Power
	External environment [a]				
Enclosure	Amateur radio further than 20 m [b]	X	X	X	X
	Broadcast transmitter operating below 1,6 MHz further than 5 km [b]	X	X	X	X
	FM and TV transmitters further than 1 km [b]	X	X	X	X
	Industrial area with limited access		X	X	X
	HV / MV substation close to sensitive area	X	X		X
	Cellular communication systems with remote base station further than 200 m (hand-held transceivers, e.g. GSM, WiMAX etc.) [b]	X	X	X	X
	Paging systems, base stations, further than 100 m [b]	X	X		X
	Aviation RADAR further than 5 km [b]	X	X	X	X
AC power	Feeding MV- or HV-line [b]	X	X	X	X
Signal	Telecommunication line [c]	X	X	X	X
	Internal environment due to the inside installation [d]				
Enclosure	Paging systems [f]	X	X		X
	Portable communication systems (hand-held transmitters, mobile phones) [e, f]	X	X		
	Limited/controlled use of portable communication systems [b]			X	X
	Presence of low power (< 100 mW) items using ISM frequencies according to CISPR 11 [b]			X	
	High concentration of ISM equipment (Group 1 according to CISPR 11) [b]	X	X	X	X
	Proximity to low-power ISM equipment (Group 2 according to CISPR 11), typically less than 1 kW [b]	X	X		
	Proximity to high-power ISM equipment (Group 2 according to CISPR 11), typically more than 1 kW [b]		X		
	Proximity to LV/MV substations closer than 20 m [b]	X	X		X
	Proximity to arc welders (mobile) [b]		X		
	Proximity to arc welders [b]		X		

Ports	Attributes	General	Heavy	Process	Power
	Proximity to HV substations [b]				X
	Proximity of medium-voltage and high-voltage lines closer than 20 m [b]		X		X
	Pipe heating systems [b]			X	
AC power	AC cabling LV [b]	X	X	X	X
	AC cabling MV [b]		X	X	X
	AC bus bar systems [b]		X		X
	Large power drive systems (> 16 A per phase) [b]		X	X	
	Power factor correction			X	
	Possibility of high fault currents		X		X
	Arc furnaces		X		
	Switching of inductive or capacitive loads	X	X		
	High-inrush loads		X		
DC power	DC distribution systems	X	X	X	X
	Rectifier		X	X	
	Switching of inductive or capacitive loads		X	X	X
	High inrush loads		X		
Signal	Outdoor exposure			X	X
	Long lines (> 30 m) [g]	X	X	X	X
	Conduit runs likely	X	X	X	X
	Separation of different cable categories by distance			X	X
	Lightning exposure	X	X	X	X
	Overvoltage/lighting protection			X	X
Earth	Equipotential bonding system	X		X	X
	Extensive ground mats, generally well controlled			X	X
	Metallic structures			X	X
	Interconnected separate ground mats			X	
	Large ground loops		X		
	Possibility of large ground fault currents		X	X	X

[a] This portion of the table presents contributors to the electromagnetic environment within a location class that are located ~~external to~~ outside the location.

[b] If the stated separation is fulfilled, the radiated field strength will not exceed the compatibility level given in Table A.1, otherwise the compatibility level needs to be adjusted.

[c] This assumes a UTP connection from the PSTN.

[d] This portion of the table presents contributors to the electromagnetic environment within a location class that are located ~~internal to~~ inside the location.

[e] This deals with the radiated signal from the handheld transceivers located within the location class.

[f] This deals with the radiated signal from both the handheld transceivers and the base stations located within the location class.

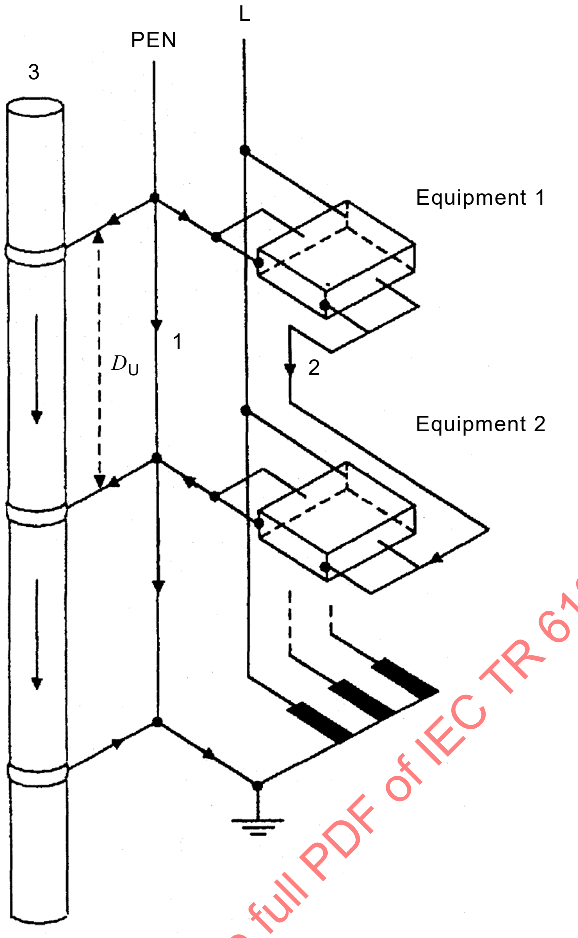
[g] This includes: Ethernet, security systems.

8.6 Types of power supply networks

Power supply networks ~~build~~ are an essential part of electrical installations, beside the electrical and electronic components, items of equipment, ~~apparatuses~~ or systems used therein. Though the purpose of such networks is to provide equipment with electrical power, they show also characteristics in terms of EMC. Depending on the type of power supply network, for example disturbances in the grounding system can be produced or the possibility and efficiency of EMC measures can be affected. In this respect the actual type of a power supply network has to be considered as a factor contributing to the electromagnetic environment.

There are several types of power networks and they can be distinguished with respect to their earthing arrangements (see IEC 60364-4-44). In case of earthed systems, i.e. systems which are connected at least at one network point to a local reference earth, mainly two types of low-voltage installations exist.

The first type is schematically shown in Figure 8 and is characterised by the fact that neutral (N) and protective conductor (PE) are combined together into only one conductor, the PEN conductor. In this type of power system (TN-C system) operating currents do not only use the neutral conductor as return path, they use as a by-pass also all the conductive components of the grounding or equipotential bonding system. The extent of the operational currents in this by-pass arrangement depends on the ratio ~~between~~ of its impedance related to that of the PEN conductor. As a result common mode currents in the power cables as well as currents in the by-pass arrangement occur with the consequential generation of power frequency magnetic fields (radiated low frequency phenomena, see 5.2). Furthermore the situation has to be taken into account that operating currents might flow in any circuits connected to the equipotential bonding system, such as the shields of signal cables (conducted low frequency phenomena, see 5.1).



Key

1 PEN conductor

2 Shielded interconnection cable

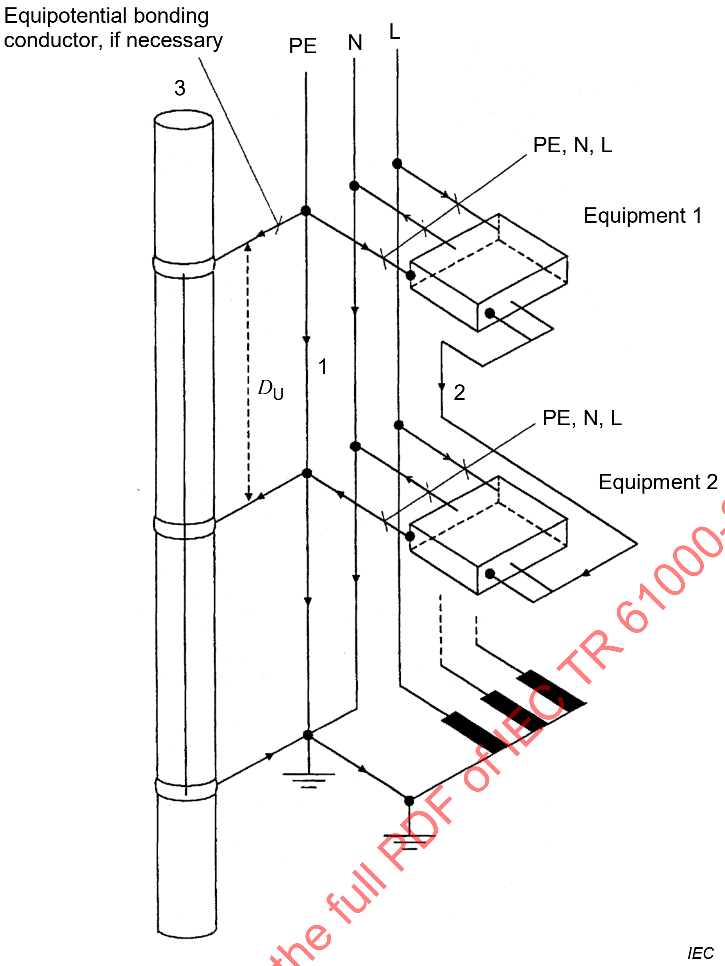
3 Metallic structure of the equipotential bonding system

L Phase conductor

D_U = voltage across the structure

Figure 8 – Situation for TN-C power installation systems

From an EMC point of view the second type of low-voltage installation should be preferred, i.e. the TN-S system. It is schematically shown in Figure 9 and here the neutral and protective earth conductors are strictly separated except at one point were both are connected but only once, for example at the low-voltage transformer or at the switchgear board. This type of installation prevents operational current from flowing outside the phase and neutral conductors. Therefore the equipotential bonding system is free of operational currents and no effects such as significant low frequency conducted and radiated phenomena are to be expected.



Key

1 PE conductor

2 Shielded interconnection cable

3 Metallic structure of the equipotential bonding system

L Phase conductor

D_U = voltage across the structure

Figure 9 – Situation for TN-S power installation systems

8.7 Alterations in electromagnetic environments

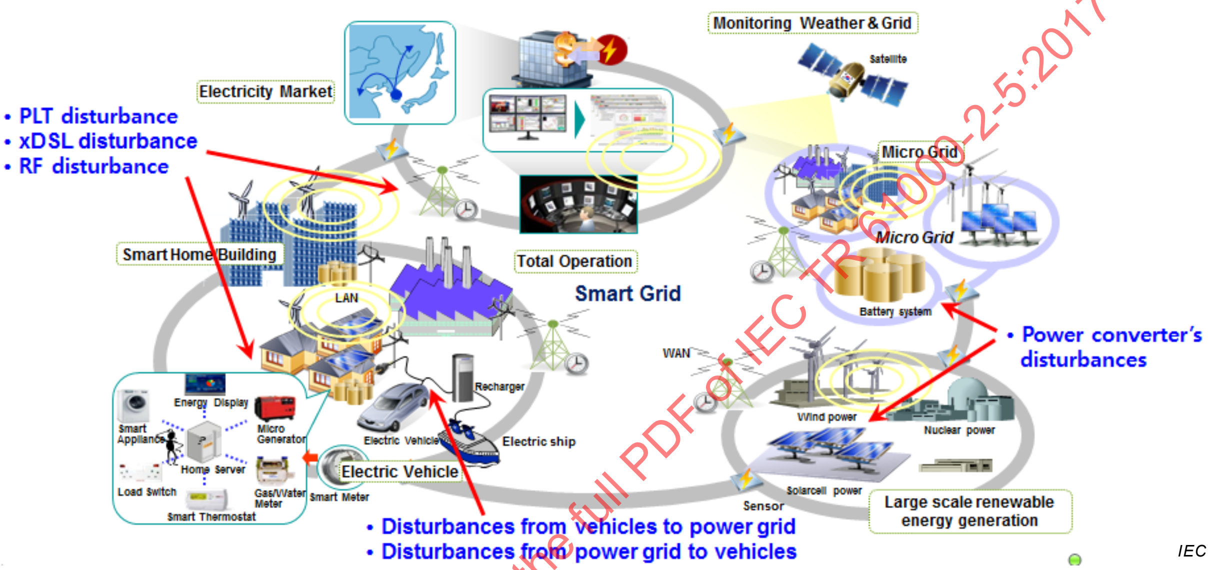
8.7.1 General

The electromagnetic environment at a location is likely to experience variations in its electromagnetic profile due to a variety of reasons. The variations experienced may be exemplified by an increase in the amplitude of electromagnetic disturbances, the presence of electromagnetic phenomena not previously observed at the location, a deterioration of equipment emissions (due to ageing, etc.), variation in the physical environmental conditions (i.e. temperature, dust, humidity etc.) of the location, etc.

System integrators and equipment installers are advised to undertake a critical review of the electromagnetic environment of their intended installation and/or undertake an electromagnetic site survey at regular intervals to ensure that the electromagnetic profile of the intended location is duly represented in the equipment EMC specification.

8.7.2 The electromagnetic environments of Smart Grid

The so-called "Smart Grid" is the term applied in many parts of the world to describe the next-generation power grid that optimizes energy efficiency by adding new information and communication technology (ICT) and controls to the existing power grid. In many locations Smart Grid will likely provide bi-directional and real-time power-exchange information between providers and consumers. During the development of Smart Grids, it is likely that existing electromagnetic environments will be modified (this usually occurs when any new technology is introduced). Many Smart Grid projects are deploying different types of communication systems (e.g., PLT, LAN, GSM, CDMA, WiMax, etc.) to control the power grid, and other types of power electronic devices (i.e. photovoltaic inverters, power converters for electric energy storage systems and vehicle chargers). A global picture of the Smart Grid situation is shown in Figure 10.



(Source: KSGA – Korea Smart Grid Association)

Figure 10 – Examples of electromagnetic environments associated with the Smart Grid

The widespread use of power inverters might lead to an increased noise level in the low-voltage distribution network. On the other hand, technologies like PLT require a limitation of emissions in the frequency range below 150 kHz to operate as intended. At the time of the drafting of this document, there was an intensive discussion in CISPR on the introduction of emission limits in the frequency range below 150 kHz to regulate these demands. On the other hand, new immunity test methods such as those in IEC 61000-4-19 have been introduced to provide corresponding immunity test methods.

8.8 Further conducted electromagnetic phenomena

8.8.1 Description of conducted phenomena other than those in Clause 4 and Clause 5

Both transient and continuous signals can be coupled directly or indirectly on conducting metallic wires and cables. The signals (voltages) can be coupled as differential signals between individual wires or as common mode voltages with respect to a reference plane, typically called ground. The sources in a location can be other equipment connected to the same wires and cables. It may also be coupled from one wire/cable to another wire/cable by electromagnetic fields.

The wire/cable lengths and separation distances are a major factor that influence the levels defined in the different location classes.

8.8.2 ~~REIN~~ Repetitive electrical impulse noise

Repetitive electrical impulse noise (REIN) is the term given to a specific phenomenon that creates both a conducted and radiated disturbance to the local electromagnetic environment.

The disturbance is characterized by a burst of noise that lasts for up to 100 µs and has a repetition frequency equal to twice the fundamental frequency of the local power network. Thus, where the fundamental frequency of the power network is 50 Hz, the REIN repetition frequency is 100 Hz (i.e. 10 ms between the onset of each burst); where the fundamental frequency of the power network is 60 Hz, the REIN repetition frequency is 120 Hz (i.e. 8,3 ms between the onset of each burst).

The conducted disturbance level is highest on LV power distribution installations, where it appears as both a common mode and differential mode disturbance. The conducted disturbance is launched onto the LV power distribution installation by attached electrical and/or electronic equipment.

The conducted disturbance level is lower on telephony distribution installations, where it again appears as a common mode and differential mode disturbance. For the telephony distribution installation, the disturbance level of the common mode disturbance is higher than that of the differential mode. This pattern indicates that common mode disturbance is coupled onto the telephony extension installation from adjacent sections of the LV power distribution installation; the differential mode disturbance arises as a result of modal conversion of the coupled common mode disturbance by the unbalance about earth of the telephony distribution installation.

Hence all items connected to the building's telephony distribution installation (i.e. voice telephony items, data modems, fax machines, etc.) will experience a simultaneous common mode and differential mode input conducted disturbance to the signal port.

The PSD of the differential mode conducted disturbance on the telephony distribution installation is as follows:

$$Noise_{\text{REIN}}(f) = \begin{cases} -86 \text{ dBm/Hz} & f \leq 316\,\text{kHz} \\ \max\left[\left(-86 - 80 \cdot \log_{10}(f(MHz)/0{,}316), -116\right]\right. \text{ dBm/Hz} & 316\,\text{kHz} < f \leq 750\,\text{kHz} \\ -116 \text{ dBm/Hz} & 750\,\text{kHz} < f < 2{,}2\,\text{MHz} \\ \max\left[(-116 - 20 \cdot \log_{10}(f(\text{MHz})/2{,}2), -150\right] \text{ dBm/Hz} & f \geq 2{,}2\,\text{MHz} \end{cases} \quad (2)$$

The PSD of the common mode conducted disturbance on the telephony distribution installation is −40 dBm/Hz in the frequency range from 150 kHz to 30 MHz.

The radiated disturbance is produced by the common mode current that is induced upon the building's LV power and telephony distribution installation. This common mode disturbance is free to propagate throughout the building's distribution installation and along the external infrastructure connected to the building.

8.8.3 ~~SHINE~~ Single high intensity noise event

Single high intensity noise event (SHINE) is the term given to a specific phenomenon that creates both a conducted and radiated disturbance to the local electromagnetic environment.

The disturbance is characterised by a burst of noise that lasts up to 4 s.

The conducted disturbance level is higher on LV power distribution installations, where it appears as both a common mode and differential mode disturbance. The conducted disturbance is launched onto the LV power distribution installation by attached electrical and/or electronic equipment.

The conducted disturbance level is lower on telephony distribution installations, where it again appears as a common mode and differential mode disturbance. For the telephony distribution installation, the disturbance degree of the common mode disturbance is higher than that of the differential mode. This pattern indicates that common mode disturbance is coupled onto the telephony extension installation from adjacent sections of the LV power distribution installation; the differential mode disturbance arises as a result of modal conversion of the coupled common mode disturbance by the unbalance about earth of the telephony distribution installation.

Hence all items connected to the building's telephony distribution installation (i.e. voice telephony items, data modems, fax machines, etc.) will experience a simultaneous common mode and differential mode input conducted disturbance to the signal port.

The PSD of the differential mode conducted disturbance on the telephony distribution installation is –86 dBm/Hz between 138 kHz to 7 MHz.

The PSD of the common mode conducted disturbance on the telephony distribution installation is –40 dBm/Hz in the frequency range from 150 kHz to 30 MHz.

The radiated disturbance is produced by the common mode current that is induced upon the building's LV power and telephony distribution installation. This common mode disturbance is free to propagate throughout the building's distribution installation and along the external infrastructure connected to the building.

8.9 Mitigation aspects

When considering disturbance voltages, the differential mode (or normal mode or symmetrical) voltage is the voltage occurring between two current-carrying conductors. The common mode (or asymmetrical) voltage is the average of the voltages of the considered conductors (at least two) and the chosen reference. This reference can be a safety earth wire, a water pipe, an instrument rack, a chassis, etc. The asymmetrical voltage is measured between one of the considered conductors and the chosen reference. The three types of voltages are not independent. For example, in the case of two "hot" conductors and a reference, the difference vector between the two asymmetrical voltage vectors gives the differential mode voltage, while half of the vector sum of these two voltages gives the common mode voltage. Hence, the phase angle ~~*~~ between the asymmetrical voltages strongly determines the amplitudes of the differential and common mode voltages relative to the asymmetrical voltages.

An important aspect of designing systems for electromagnetic compatibility is to recognize that significant voltage differences can exist between the conductors of different systems, such as the power system and a data link system. These voltage differences are determined by the amplitudes of the disturbances occurring in the respective system, and the bonding and grounding practices mandated and implemented, or existing by default at the particular site. The disturbance degrees cited in Clause 5, especially for AC mains, are given for "no protective devices installed" cases.

However, protective schemes, such as filters or surge protective devices installed at the mains port of the equipment, can produce changes in the voltage difference between protective earth conductors and local "ground" at the site of the equipment. This situation motivates consideration of a reference medium with disturbance voltages applicable to reference conductors belonging to different systems, where each can have its own (and different) ground or earth reference.

In the location tables shown in Annex A, disturbance degrees have been selected to define the environment levels recommended for several location classes. These disturbance degrees, resulting from their sources, have been defined in Clauses 5, 6 and 7. For each location class, a listing of the major electromagnetic attributes of that location, together with necessary explanatory notes, is given in 8.1 through 8.5.

8.10 Description of location classes with regard to the requirements of EMC basic standards

The electromagnetic environment at a location of interest is a fact ~~on its own~~ per se and in most cases it cannot be related one-to-one to the descriptions of electromagnetic phenomena as they are given for example in EMC basic standards of IEC 61000-4 (all parts). The detailed manifestation of electromagnetic phenomena depends on many parameters and conditions, such as the electromagnetic characteristics of equipment operating at a location of interest or the installation practice applied and in most cases those phenomena do not show the same characteristics as described in an EMC basic standard.

However, when immunity requirements are to be specified that reflect the stress due to an electromagnetic environment, it is in most cases not a practical approach to develop new immunity tests which consider the particular manifestation of electromagnetic phenomena at a location of interest. Such specific immunity tests would consider a single situation at a single point in time only.

On the other hand, there are already a lot of standardized immunity tests available, such as those of IEC 61000-4 (all parts). In many cases ~~it can be taken advantage of~~ those EMC basic standards can be used when their immunity tests reflect the electromagnetic phenomena at a location of interest in a certain extent. This means that such standardized tests can be used, either directly or partly modified, to conclude on corresponding immunity requirements. Hence in many cases an approach might be followed where the stress due to an electromagnetic environment is reflected by the application of appropriate immunity standards. Table 49 provides an overview of the electromagnetic phenomena as compared to EMC basic standards.

~~NOTE~~ The assessment of the extent to which a standardized immunity test reflects an electromagnetic phenomenon in real environment represents a crucial task and needs careful evaluation.

As the various location classes are characterized by different electromagnetic phenomena, different with respect to their occurrence as well as different with respect to their disturbance degrees, different immunity requirements result for equipment intended to be used at those various location classes and hence different sets of EMC basic standards may apply, also different in the applied immunity test level. Special attention, however, should be paid to the fact of whether equipment is intended to be used at locations which are assigned to different location classes.

Table 49 – Overview of phenomena versus basic standard, related table and subclause

Phenomena		Basic test standard	See table of this document	See sub-clause in this document	Remark
LF-conducted					
Power supply networks	Harmonics	IEC 61000-4-13	2	5.1.1	IEC 61000-2-2 IEC 61000-2-4 IEC 61000-2-12
	Voltage amplitude variations	IEC 61000-4-14	3	5.1.2.1 a)	IEC 61000-2-4
	Voltage dips	IEC 61000-4-11	None	5.1.2.1 b)	
	Voltage interruptions	IEC 61000-4-11	None	5.1.2.1 c)	
	Voltage unbalance	IEC 61000-4-27	4	5.1.2.1 d)	IEC 61000-2-2 IEC 61000-2-4 IEC 61000-2-12
	Voltage frequency variations	IEC 61000-4-28	5	5.1.2.2	IEC 61000-2-2 IEC 61000-2-4 IEC 61000-2-12
Power supply networks	Common mode voltages	IEC 61000-4-16	6	5.1.3	
	Signalling voltage 0,1 kHz to 3 kHz	IEC 61000-4-13	7	5.1.4	EN 50065
	Induced LF	IEC 61000-4-16	8	5.1.6	EN 50065
	DC in AC networks		None	5.1.7	
Signal and control cables	Induced LF (normal conditions)	IEC 61000-4-16	8	5.1.6	
	Induced LF (fault conditions)	IEC 61000-4-16	8	5.1.6	
LF – radiated					
LF magnetic field	DC	IEC 61000-4-8 [a]	9	5.2.1	
	Railway	IEC 61000-4-8 [a]	9	5.2.1	
	Power system	IEC 61000-4-8	9	5.2.1	
	Power system harmonics (n = harmonics)	IEC 61000-4-8 [a]	9	5.2.1	
	not power system related	IEC 61000-4-8 [a]	9	5.2.1	
LF electric field	DC lines		10	5.2.2	
	Railway (~~16 2/3~~ 16,7 Hz)		10	5.2.2	IEC TR 61000-2-3
	Power system (50 Hz to 60 Hz)		10	5.2.2	
HF ~~phenomena~~ – conducted					
Direct-conducted CW	PLT	IEC ~~61000-4-6~~ 61000-4-19	~~None~~ 11	6.1.2	
HF-conducted induced CW	10 kHz to150 kHz	IEC 61000-4-16	12	6.1.3	
	0,15 MHz to 150 MHz	IEC 61000-4-6	12	6.1.3	

Phenomena		Basic test standard	See table of this document	See sub-clause in this document	Remark
HF-conducted signalling	3 kHz to 95 kHz	IEC 61000-4-19	7	5.1.4	EN 50065
	95 kHz to 148,5 kHz	IEC 61000-4-19	7	5.1.4	EN 50065
	148,5 kHz to 500 kHz	IEC 61000-4-19	7	5.1.4	EN 50065
Unidirectional transients	Nanoseconds	IEC 61000-4-4	13	6.1.4	
	Microseconds, close	IEC 61000-4-5	13	6.1.4	
	Microseconds, distant	IEC 61000-4-5	13	6.1.4	
	Milliseconds	IEC 61000-4-5	13	6.1.4	
HF-conducted oscillatory transients	High frequency	IEC 61000-4-12 IEC 61000-4-18	14	6.1.4	
	Medium frequency	IEC 61000-4-12 IEC 61000-4-18	14	6.1.4	
	Low frequency	IEC 61000-4-12 IEC 61000-4-18	14	6.1.4	
HF radiated					
Radiated CW	ISM Group 2	IEC 61000-4-3	16	6.2.2	CISPR 11
Radiated modulated	Mobile units GSM DCS1800 DECT	IEC 61000-4-3	21, 22	6.2.3.2	
	Base stations	IEC 61000-4-3	23, 24	6.2.3.2	
	Medical and biological telemetry items	IEC 61000-4-3	25	6.2.3.2	
	Digital television broadcast	IEC 61000-4-3	26, 27, 28	6.2.3.2	
	Unlicensed radio services	IEC 61000-4-3	29, 30	6.2.3.2	
	Paging services (base station)	IEC 61000-4-3	32	6.2.3.2	
	RFID + railway transponder	IEC 61000-4-3	39,40	6.2.3.3	
	Other RF items	IEC 61000-4-3	19,20 33 to 38	6.2.3.2	
	Amateur radio stations	IEC 61000-4-3	17, 31	6.2.3.1 6.2.3.2	
	CB	IEC 61000-4-3	18	6.2.3.1	
Radiated pulsed	Radiated transients	IEC 61000-4-9 IEC 61000-4-10	41	6.2.4	
	RADAR	IEC 61000-4-3	42	6.2.4	
ESD	Slow	IEC 61000-4-2	43, 44	7.2 / 7.3	
	Fast	IEC 61000-4-2	43, 44	7.2 / 7.3	

NOTE In some cases where IEC 61000-4-3 is indicated, the basic test standards IEC 61000-4-20 and IEC 61000-4-21 ~~may~~ can be used.

[a] Frequency range not covered by IEC 61000-4-8, but test principle and setup of this standard can be used.

9 Principles of the selection of immunity levels

9.1 Approach

The design, manufacturing, installation and maintenance of an item with a high degree of immunity can be a costly process if proper practices are not applied. The immunity requirements should, therefore, be selected carefully. The proposed approach is that immunity should be selected according to:

a) the electromagnetic environment in which the item will be used;

b) the criticality of the different possible interferences.

Different immunity characteristics might be appropriate for the different functions of a multi-function item. For instance, a safety-related function should have a higher immunity level than a convenience-related function. Therefore, a more rigorous approach should take into consideration the need for undisturbed operation of each function performed by an item. However, it would not be realistic to require this selective specification of immunity as a general requirement, because available data are generally insufficient or imprecise.

The choice of different immunity characteristics for different functions of the same item is relevant because of the statistical nature of an electromagnetic environment, an aspect of EMC which has been recently emphasized. It should be stressed that the proposed approach is not only relevant for very complex systems having many different functions.

9.2 Uncertainties

9.2.1 Uncertainties in the test situation

Immunity test levels are the levels to be considered in the test situation. A test level is the magnitude of a quantity as measured in a well-defined method in a well-defined setup. However, there are several kinds of uncertainties that can influence an immunity test (see for example IEC 61000-4-3 or CISPR TR 16-4-1):

– precision and calibration of instrumentation;

– definition of the test setup;

– definition of the setup of the equipment under test.

These uncertainties can be assessed by checking the reproducibility of a given test, when all specifications in the relevant standards are fulfilled. Depending on the type of measurement being made, such uncertainties generally lie in the 1 dB to 6 dB range, according to the type of measurement and the quality of the specification contained in the standard. Note that some test setups and test methods may be subject to higher uncertainties, however, standards and methods of measurement are continuously being improved.

The relevance of an immunity test is strongly determined by the degree to which it is possible to represent the actual distribution of a particular disturbance in the equipment under test by means of a test source and coupling network(s) connected to some ports of the equipment under test.

9.2.2 Uncertainties in the application situation

In the application situation, uncertainties are mainly related to the likelihood of the occurrence of a strong disturbance source that was not expected to be there.

9.2.3 Dealing with uncertainties

Dealing with uncertainties should be affected by selection of appropriate margins between the expected level of disturbances and the immunity limit. One of these margins will be selected for each equipment function depending upon its criticality. The use of an item of equipment in any controlled or uncontrolled environment could also influence the choice of the margins.

Therefore, an item of equipment can be tested at different levels for its different functions. The choice of the appropriate margin for each function should be carried out by the relevant IEC product committee.

9.3 Dealing with high density sources

There are occasions where the local electromagnetic environment is characterized by a high concentration of identical emission sources or a combination of multiple emission sources (i.e. separate equipment items). The resultant electromagnetic field at such a location may be analysed as a superposition of the electromagnetic fields due to the individual emission sources provided the emissions sources operate at a common frequencies and in the same polarity (or where the unintentional emissions from the sources can be assumed to be identical). Where the emissions sources operate at different frequencies, common emission frequencies per polarity can be identified.

The superposition of the electromagnetic fields due to multiple emissions sources has the potential to produce a system emissions level that is greater than the system emissions limit (as defined in an applicable product standard or generic standard). Such a situation would result where the individual noise sources are not intentionally assembled together as a system but are installed in close proximity as individual systems. The peak of the resultant electromagnetic field at the observation point would be a function of the individual emissions amplitude and of the phase difference between the individual emissions and an agreed reference at the observation point. At the point of observation, the peak emission amplitude per frequency can be expressed mathematically as:

$$E_i(t) = E_{0i} \cos(\alpha \pm \omega t) \quad (3)$$

where

– $E_i(t)$ is the instantaneous radiated emission level due to the i^{th} radiated emission at time t, at the point of observation,

– $E_{0i}(t)$ is the amplitude of the i^{th} radiated emissions at the point of observation,

– α_i is the phase difference between the i^{th} radiated emission and some agreed reference at the point of observation.

In estimating the peak emission, consideration of the propagation path and the influence of physical boundaries on the field strength need to be taken into account.

Where individual noise sources are intentionally assembled together as a system at a location, the installer is bound by the local regulation to ensure that the installation complies with the relevant system emissions limit.

9.4 Criticality criteria

Several levels of criticality can be considered that involve all the consequences of an interference. Depending upon the nature and mission of the item and its associated equipment, criteria for the definition of criticality can include:

– catastrophic interference: interference which might cause death, or major injuries, or extensive damage, or might lead to other considerable detrimental consequences;

– critical interference: interference which can result in minor injuries or extensive damage to equipment, or might lead to other important detrimental consequences;

– major interference: interference which can result in minor permanent damage to equipment, or can lead to other moderate detrimental consequences;

– minor interference: interference which can cause temporary loss of performance, and can have other minor detrimental consequences;

– inconsequential interference: interference which only causes loss of performance within tolerances, and does not require human intervention.

From this classification, it is clear that the criticality of an interference depends not only on the item under consideration, but also on all interactions between the item and the outside world. It should be kept in mind that a minor interference for the item of interest could have catastrophic consequences for the system in which it is included (for example, interference on the communication system of an aeroplane).

Generalized performance criteria A, B and C as defined in the generic EMC standards and also the more precise performance criteria as defined in EMC product or product family standards are not related to functional safety aspects and should therefore not be used as performance criteria for safety related functions even if testing with increased test levels. Therefore a specific performance criterion ~~FS~~ DS is defined taking into account functional safety aspects.

10 Disturbance levels of the various location classes

Annex A shows three tables that describe the disturbance levels to be expected in the three location classes. All the electromagnetic phenomena relevant for a location class are considered as well as the ports applicable to those phenomena. The description of the disturbance levels is done by means of disturbance degrees.

In this document the maximum electromagnetic disturbance, obtainable at a particular location or at a port of an item, is expressed in terms of disturbance levels. The disturbance levels specified may therefore equate to that at which compatibility is assured (then representing compatibility levels) or may exceed the level at which compatibility is assured. Some of the tables within this document, therefore specify compatibility levels as disturbance levels; this is particularly true for tables dealing with low frequency conducted phenomena.

The entries showing the disturbance levels should be read in such a way that an electromagnetic phenomenon is typically to be expected at the relevant port, and this with a typical maximum disturbance level indicated by the disturbance degree derived from the tables in Clause 5.

For example, Table A.3 shows that induced conducted high frequency disturbances (row entitled “HF-conducted”) have to be taken into account on AC and DC power lines and on signal lines. Details concerning the phenomenon are described in 6.1.2 and Table 11. For those lines a disturbance degree of 4 should be considered. This means that corresponding immunity tests should have at least an immunity level of 10 V. The appropriate immunity test method can be derived from Table 49 which in this case is the immunity test according to ~~be~~ IEC 61000-4-6.

The disturbance levels given in the tables in Annex A were derived on the basis of

– results of measurements (e.g. in the frame of site surveys);
– experience from the past;
– technical judgment in connection with engineering arguments.

Hence the disturbance levels should be looked at as typical values of disturbances to be typically expected in an electromagnetic environment. However, it should be kept in mind that those typical values are not necessarily the maximum or worst-case ones. There are installations, for example with particular ISM equipment, where much higher field strength levels might occur than described by means of disturbance degrees in a typical environment.

Annex A
(informative)

Compatibility levels/disturbance levels for location classes

The tables of Annex A give the compatibility levels/disturbance degrees for the phenomena relevant in the location class under consideration.

Table A.1 to Table A.3 present the environment that assumes that radio transmitters such as amateur radio, paging systems, and CB are at least not normally located within the location or not closer than indicated in the tables in which the attributes of the location classes are described. If, however, such transmitters are located at the location the disturbance degree can be expected to increase, requiring that the compatibility level be re-assessed.

Table A.1 – Disturbance levels in the residential location class

Phenomenon		For details concerning phenomenon, see subclause	For details regarding disturbance degree, see table	Disturbance degrees for each port				
				Enclosure	AC power	DC power	Signal	Earth
LF-conducted	Harmonics	5.1.1	2	—	2	—	—	—
	Power supply voltage amplitude variations	5.1.2.1	3	—	2	—	—	—
	Power supply voltage unbalance	5.1.2.1	4	—	2	—	—	—
	Voltage dips	5.1.2.1		—	a	—	—	—
	Short interruptions	5.1.2.1		—	a	—	—	—
	Power supply voltage frequency variations	5.1.2.2	5	—	2	—	—	—
	Power supply network common mode voltages	5.1.3	6	—	1	—	—	—
	Signalling	5.1.4	7	—	1	—	—	—
	Induced low-frequency voltages	5.1.6	8	—	—	—	1	—
	DC voltage in AC networks	5.1.7		—	b	—	—	—
LF-radiated	Magnetic fields	5.2.1	9	2	—	—	—	—
	Electric fields	5.2.2	10	1	—	—	—	—
HF-conducted	Direct conducted CW	6.1.2		—	b	—	b	—
	Induced CW	6.1.3	11	—	3	3	3	—
	Transients – unidirectional	6.1.4	12					
	Nanoseconds			—	2	1	1	—
	Microseconds			—	2	1	1	—
	Milliseconds			—	1	—	—	—

Phenomenon		For details concerning phenomenon, see subclause	For details regarding disturbance degree, see table	Disturbance degrees for each port				
				Enclosure	AC power	DC power	Signal	Earth
	Transients – oscillatory	6.1.4	13					
	Low frequency			—	3	—	1	—
	Medium frequency			—	2	—	1	—
	High frequency			—	1	—	1	—
HF-radiated	Radiated CW – ISM equipment	6.2.2	16	2	—	—	—	—
	Radiated modulated below 30 MHz	6.2.3.1						
	Amateur radio		17	3	—	—	—	—
	CB radio		18	2	—	—	—	—
	AM broadcasting		19	2	—	—	—	—
	Radiated modulated 30 MHz to 1 000 MHz	6.2.3.2						
	Analogue services		20	3	—	—	—	—
	Mobile units of phones		21, 22	4	—	—	—	—
	Base stations of phones	Outside	23, 24	3	—	—	—	—
		Inside	23, 24	5	—	—	—	—
	Medical/biological telemetry		25	2	—	—	—	—
	Unlicensed radio services 1		29	3	—	—	—	—
	Unlicensed radio services 2		30	4	—	—	—	—
	Amateur radio > 30 MHz		31	3	—	—	—	—
	Paging services/base		32	1	—	—	—	—
	TETRA		37	2	—	—	—	—

Phenomenon		For details concerning phenomenon, see subclause	For details regarding disturbance degree, see table	Disturbance degrees for each port				
				Enclosure	AC power	DC power	Signal	Earth
	Radiated modulated 1 GHz to 6 GHz	6.2.3.2						
	Mobile units of phones		21, 22	4	—	—	—	—
	Base stations	Outside	23, 24	3	—	—	—	—
		Inside	23, 24	5	—	—	—	—
	Amateur radio		31	3	—	—	—	—
	Other RF services (1)		33	5	—	—	—	—
	Other RF services (2)		34	4	—	—	—	—
	UWB		37	1	—	—	—	—
	Radiated modulated above 6 GHz	6.2.3.2						
	Amateur radio		31	3	—	—	—	—
	Other RF items (3)		35	4	—	—	—	—
	Other RF items (4)		36	1	—	—	—	—
	UWB		37	1	—	—	—	—
	Other RF items (6)		38	c	—	—	—	—
	RFID	6.2.3.3	39	2	—	—	—	—
			40	2	—	—	—	—
	Radiated pulsed disturbances	6.2.4	41	2	—	—	—	—
			42	1	—	—	—	—
ESD	Slow	7.2	43	3	—	—	—	—
	Fast	7.2	43	3	—	—	—	—
	Fields	7.3	44	3	—	—	—	—

a See NOTE 2 below Figure 3.

b Under consideration.

c Services not widely used.

Table A.2– Disturbance levels in the commercial/public location class

Phenomenon		For details concerning phenomenon, see subclause	For details regarding disturbance degree, see table	Disturbance degrees for each port				
				Enclosure	AC power	DC power	Signal	Earth
LF-conducted	Harmonics	5.1.1	2	—	3	—	—	—
	Power supply voltage amplitude variations	5.1.2.1	3	—	2	—	—	—
	Power supply voltage unbalance	5.1.2.1	4	—	2	—	—	—
	Voltage dips	5.1.2.1		—	a	—	—	—
	Short interruptions	5.1.2.1		—	a	—	—	—
	Power supply voltage frequency variations	5.1.2.2	5	—	2	—	—	—
	Power supply network common mode voltages	5.1.3	6	—	2	—	—	—
	Signalling	5.1.4	7	—	1	—	—	—
	Induced low-frequency voltages	5.1.6	8	—	—	—	2	—
	DC voltage in AC networks	5.1.7		—	b	—	—	—
LF-radiated	Magnetic fields	5.2.1	9	2	—	—	—	—
	Electric fields	5.2.2	10	1	—	—	—	—
HF-conducted	Direct conducted CW	6.1.2		—	b	—	b	—
	Induced CW	6.1.3	11	—	3	3	3	—
	Transients – unidirectional	6.1.4	12					
	Nanoseconds			—	2	1	1	—
	Microseconds			—	2	1	1	—
	Milliseconds			—	2	—	—	—

Phenomenon		For details concerning phenomenon, see subclause	For details regarding disturbance degree, see table	Disturbance degrees for each port				
				Enclosure	AC power	DC power	Signal	Earth
	Transients – oscillatory	6.1.4	13					
	Low frequency			—	3	—	1	—
	Medium frequency			—	2	—	1	—
	High frequency			—	2	—	1	—
HF-radiated	Radiated CW – ISM equipment	6.2.2	16	2	—	—	—	—
	Radiated modulated below 30 MHz	6.2.3.1						
	Amateur radio		17	3	—	—	—	—
	CB radio		18	2	—	—	—	—
	AM broadcasting		19	2	—	—	—	—
	Radiated modulated 30 MHz to 1 000 MHz	6.2.3.2						
	Analogue services		20	3	—	—	—	—
	Mobile units of phones		21, 22	4	—	—	—	—
	Base stations of phones	Outside	23, 24	3	—	—	—	—
		Inside	23, 24	5	—	—	—	—
	Medical/bio. telemetry		25	2	—	—	—	—
	Unlicensed radio services 1		29	3	—	—	—	—
	Unlicensed radio services 2		30	4	—	—	—	—
	Amateur radio > 30 MHz		31	3	—	—	—	—
	Paging services/base		32	1	—	—	—	—
	TETRA		37	3	—	—	—	—

Phenomenon		For details concerning phenomenon, see subclause	For details regarding disturbance degree, see table	Disturbance degrees for each port				
				Enclosure	AC power	DC power	Signal	Earth
	Radiated modulated 1 GHz to 6 GHz	6.2.3.2						
	Mobile units of phones		21, 22	4	—	—	—	—
	Base stations	Outside	23, 24	3	—	—	—	—
		Inside	23, 24	5	—	—	—	—
	Amateur radio		31	3	—	—	—	—
	Other RF services 1		33	5	—	—	—	—
	Other RF services 2		34	4	—	—	—	—
	UWB		37	1	—	—	—	—
	Radiated modulated above 6 GHz	6.2.3.2						
	Amateur radio		31	3	—	—	—	—
	Other RF items (3)		35	4	—	—	—	—
	Other RF items (4)		36	1	—	—	—	—
	UWB		37	1	—	—	—	—
	Other RF items (6)		38	c	—	—	—	—
	RFID	6.2.3.3	39	3	—	—	—	—
			40	3	—	—	—	—
	Radiated pulsed disturbances	6.2.4	41	2	—	—	—	—
			42	1	—	—	—	—
ESD	Slow	7.2	43	3	—	—	—	—
	Fast	7.2	43	3	—	—	—	—
	Fields	7.3	44	3	—	—	—	—

a See NOTE 2 below Figure 3.

b Under consideration.

c Services not widely used.

Table A.3 – Disturbance levels in the industrial location class

Phenomenon		For details concerning phenomenon, see subclause	For details regarding disturbance degree, see table	Disturbance degrees for eachport				
				Enclosure	AC power	DC power	Signal	Earth
LF-conducted	Harmonics	5.1.1	2	—	3	—	—	—
	Power supply voltage amplitude variations	5.1.2.1	3	—	3	—	—	—
	Power supply voltage unbalance	5.1.2.1	4	—	3	—	—	—
	Voltage dips	5.1.2.1		—	a	—	—	—
	Short interruptions	5.1.2.1		—	a	—	—	—
	Power supply voltage frequency variations	5.1.2.2	5	—	3	—	—	—
	Power supply network common mode voltages	5.1.3	6	—	3	—	—	—
	Signalling	5.1.4	7	—	1	—	—	—
	Induced low-frequency voltages	5.1.6	8	—	—	—	3	—
	DC voltage in AC networks	5.1.7		—	b	—	—	—
LF-radiated	Magnetic fields	5.2.1	9	3	—	—	—	—
	Electric fields	5.2.2	10	2	—	—	—	—
HF-conducted	Direct conducted CW	6.1.2		—	b	—	b	—
	Induced CW	6.1.3	11	—	4	4	4	—
	Transients – unidirectional	6.1.4	12					
	Nanoseconds			—	4	2	2	—
	Microseconds			—	3	2	2	—
	Milliseconds			—	1	—	—	—

Phenomenon		For details concerning phenomenon, see subclause	For details regarding disturbance degree, see table	Disturbance degrees for eachport				
				Enclosure	AC power	DC power	Signal	Earth
	Transients – oscillatory	6.1.4	13					
	Low frequency			—	3	—	1	—
	Medium frequency			—	2	—	1	—
	High frequency			—	1	—	1	—
HF-radiated	Radiated CW – ISM equipment	6.2.2	16	4	—	—	—	—
	Radiated modulated below 30 MHz	6.2.3.1						
	Amateur radio		17	3	—	—	—	—
	CB radio		18	2	—	—	—	—
	AM broadcasting		19	2	—	—	—	—
	Radiated modulated 30 MHz to 1 000 MHz	6.2.3.2						
	Analogue services		20	3	—	—	—	—
	Mobile units of phones		21, 22	3	—	—	—	—
	Base stations of phones	Outside	23, 24	3	—	—	—	—
		Inside	23, 24	5	—	—	—	—
	Medical/bio. telemetry		25	1	—	—	—	—
	Unlicensed radio services 1		29	2	—	—	—	—
	Unlicensed radio services 2		30	4	—	—	—	—
	Amateur radio > 30 MHz		31	3	—	—	—	—
	Paging services/base		32	2	—	—	—	—
	TETRA		37	2	—	—	—	—

Phenomenon		For details concerning phenomenon, see subclause	For details regarding disturbance degree, see table	Disturbance degrees for eachport				
				Enclosure	AC power	DC power	Signal	Earth
	Radiated modulated 1 GHz to 6 GHz	6.2.3.2						
	Mobile units of phones		21, 22	4	—	—	—	—
	Base stations	Outside	23, 24	3	—	—	—	—
		Inside	23, 24	5	—	—	—	—
	Amateur radio		31	3	—	—	—	—
	Other RF services (1)		33	4	—	—	—	—
	Other RF services (2)		34	3	—	—	—	—
	UWB		37	1	—	—	—	—
	Radiated modulated above 6 GHz	6.2.3.2						
	Amateur radio		31	3	—	—	—	—
	Other RF items (3)		35	4	—	—	—	—
	Other RF items (4)		36	1	—	—	—	—
	UWB		37	1	—	—	—	—
	Other RF items (6)		38	c	—	—	—	—
	RFID	6.2.3.3	39	4	—	—	—	—
			40	4	—	—	—	—
	Radiated pulsed disturbances	6.2.4	41	3	—	—	—	—
			42	1	—	—	—	—
ESD	Slow	7.2	43	3	—	—	—	—
	Fast	7.2	43	3	—	—	—	—
	Fields	7.3	44	3	—	—	—	—

[a] See NOTE 2 below Figure 3.

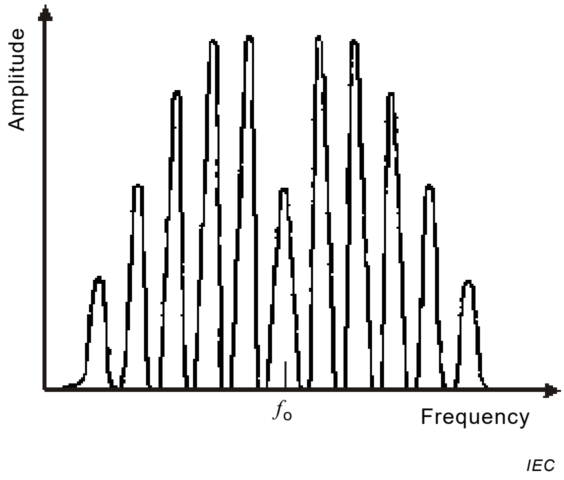
[b] Under consideration.

[c] Services not widely used.

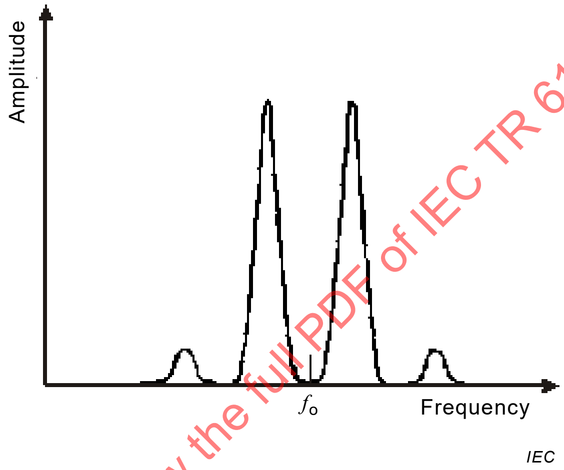
Annex B
(informative)

Radiated continuous disturbances

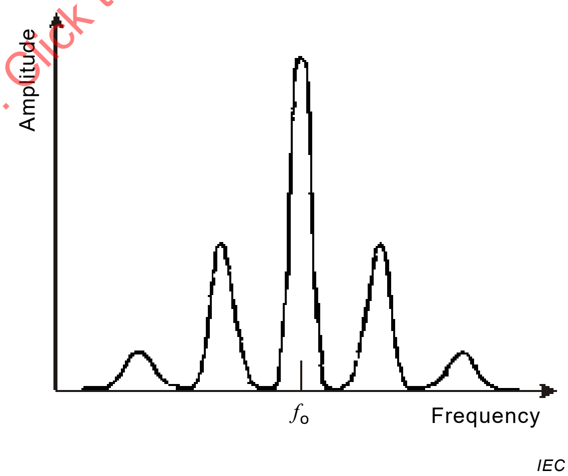
Radiated disturbances usually appear as a modulated carrier. Typical waveforms are given below. Figure B.1a) is an FM or ΦM (phase modulation) signal, Figure B.1b) is a double side band – suppressed carrier (DSB-SC) signal and Figure B.1c) is an AM signal with single tone modulation.



a) – Typical waveform of a radiated disturbance with an FM signal



b) – Typical waveform of a radiated disturbance with a double side band – Suppressed carrier signal



c) – Typical waveform of a radiated disturbance with an AM signal

Figure B.1 – Typical waveforms for radiated disturbances

Typical sources of radiated fields can be:

– broadcasting transmitters;

– other fixed transmitters (e.g. base stations, wireless access point);

– portable and mobile transmitters;
– certain ISM equipments.

Many pulsed disturbances, such as the signals produced by radars and mobile phones using TDMA techniques, are bursts of oscillation-type radiated fields. A source which has a significant emission at harmonics of a fundamental frequency can be considered as emitting several distinct continuous oscillatory radiated disturbances, an example being the emission of a pulse width modulation switched-mode power supply.

In many cases, the interference likely to be produced by a radiated disturbance depends upon the modulation. The polarization is also important where it is well defined, for instance for the field produced by an antenna in its vicinity. These aspects are not accounted for in Annex B.

In addition to the information given in 6.2 regarding disturbance levels, disturbance degrees and related field strength levels the following tables (Table B.1 to Table B.6) provide some technical data concerning various types of radiation sources. Table B.7 lists the amateur radio frequencies used in the ITU regions 1to 3.

Table B.1 – Examples of field strengths from authorized transmitters

Service	Frequency range in MHz	ERP	Typical range of separation distance	Calculated field strength range in V/m [a]
LF broadcast and maritime	0,014 to 0,5	2 500 kW	2 km to 20 km	5,5 to 0,55
AM broadcast	0,2 to 1,6	50 kW to 800 kW	0,5 km to 2 km	12,5 to 0,78
HF communications including SW broadcasting	1,6 to 30	10 kW	1 km to 20 km	0,7 to 0,04
Fixed and mobile commutations	29 to 40 68 to 87 146 to 174 422 to 432 438 to 470 860 to 990	50 W to 130 W 50 W to 130 W 50 W to 130 W 50 W to 130 W 50 W to 130 W 50 W to 130 W	2 m to 200 m	40 to 0,25
Portable telephones including cordless phones	1 880 to 1 990	5 W 1 W (DECT)	1 m to 100 m 0,5 m to 10 m	15,6 to 1,56 14 to 0,7
VHF TV	48 to 68 174 to 230	100 kW to 320 kW	0,5 km to 2 km	8 to 1,11 [b]
FM broadcast	88 to 108	100 kW	0,25 km to 1 km	8,9 to 2,2 [b]
UHF TV	470 to 853	500 kW	0,5 km to 3 km	10 to 1,6 [b]

[a] Calculated using the formula

$$E = 7\frac{\sqrt{P_{\text{ERP}}}}{r}$$

assuming that the transmitting antenna behaves as a half-wave dipole in free space and in the far field.

[b] The field strengths indicated are only present within the beam width of the transmitting antenna.

Table B.2 – Specifications of mobile and portable units

Parameters	System name								
	GSM	DCS 1800	DECT	CT-2	PDC	PHS	NADC	IMT-2000 TDD	IMT-2000 FDD
Transmitter frequency range in MHz	890 to 915	1 710 to 1 784	1 880 to 1 960	864 to 868	940 – 956 and 1 429 – 1 435	1 895 to 1 918	825 to 845	1 900 to 1 920	1 920 to 1 980
Access technique	TDMA	TDMA	TDMA / TDD	FDMA / TDD	TDMA	TDMA / TDD	TDMA	CDAM / TDMA TDD	CDAM / TDMA TDD
Burst repetition frequency	217 Hz	217 Hz	100 Hz	500 Hz	50 Hz	200 Hz	50 Hz	N/A	N/A
Duty cycle	1:8	1:8	1:24 (also 1:48 and 1:12)	1:12	1:3	1:8	1:3	Continuous	Continuous
Maximum burst power	0,8 W; 2 W; 5 W; 8 W; 20 W	0,25 W; 1 W; 4 W	0,25 W	<10 mW	0,8 W; 2 W	80 mW	<6 W	0,25 W	0,25 W
Secondary modulation	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	None	None		None	None	None	None
Geographical area	World-wide	World-wide	Europe	Europe		Japan	US	Europe	Europe

NOTE CT-3 is considered to be covered by DECT.

Table B.3 – Specifications of base stations

Parameters	System name								
	GSM	DCS 1800	DECT	CT-2	~~PDC~~	PHS	NADC	IMT-2000 TDD	IMT-2000 FDD
Transmitter frequency range in MHz	935 to 960	1 805 to 1 880	1 880 to 1 960	864 to 868	~~810 – 826 and 1 477 – 1 501~~	1 895 to 1 918	870 to 890	1 900 to 1 920	2 110 to 2 170
Access technique	TDMA	TDMA	TDMA / TDD	FDMA / TDD	~~TDMA~~	TDMA / TDD	TDMA	CDMA / TDMA TDD	CDMA / TDMA FDD
Burst repetition frequency	217 Hz	217 Hz	100 Hz	500 Hz	~~50 Hz~~	200 Hz	50 Hz	N/A	N/A
Duty cycle	1:8 to 8:8	1:8 to 8:8	1:2	1:2	~~1:3 – 3:3~~	1:8	1:3 to 3:3	Continuous	Continuous
Maximum burst power	2,5 W to 320 W	2,5 W to 200 W	0,25 W	0,25 W	~~1 W – 96 W~~	10 mW to 500 mW	500 W	20 W	20 W
Secondary modulation	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	None	None		None	None	None	None
Geographical area	Worldwide	Worldwide	Europe	Europe		Japan	US	Europe	Europe
NOTE CT-3 is considered to be covered by DECT.									

Table B.4 – Specification of other typical RF items

Parameters	System name				
	RTTT	Wideband data transmission system and HIPERLANs	Wideband data transmission system and HIPERLANs	Wideband data transmission system and HIPERLANs	Non specific short range devices
Transmitter frequency in MHz	5 795 to 5 815	2 400 to 2 483,5	5 150 to 5 350	5 470 to 5 725	2 400 to 2 483,5
Modulation type	None	FHSS	None	None	None
Maximum ERP	2 W or 8 W	100 mW and spectrum power density limitation	200 mW mean	1 W mean	10 mW 25 mW
Duty cycle	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions
Channel spacing	5 MHz or 10 MHz within some frequency ranges	None	None	None	None
Geographical area	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide

Table B.4 may be used as reference for Table 34 in 6.2.3.2.

Table B.5 – Data regarding RFID technology

Frequency range	Coupling mode	Permitted field strength or transmission power	Comments
< 135 kHz (LF)	Inductive	72 dB(µA/m)	Low frequency
3,155 MHz to 3,4 MHz		13,5 dB(µA/m)	Used for electronics article surveillance (EAS).
6,765 MHz to 6,795 MHz	Inductive	42 dB(µA/m)	Medium frequency
7,4 MHz to 8,8 MHz		9 dB(µA/m)	Used for EAS
13,553 MHz to 13,567 MHz	Inductive	60 dB(µA/m)	Medium frequency
26,957 MHz to 27,283 MHz	Inductive	42 dB(µA/m)	Medium frequency Note that 27,095 MHz is reserved for railway applications in Europe
433 MHz	Backscatter	10 mW_{ERP}	Ultra high frequency. Medium frequency
865 MHz to 868 MHz		100 mW_{ERP}	Ultra high frequency. Used for RFID only
865,6 MHz to 867,6 MHz		2 W_{ERP}	Ultra high frequency. Used for RFID only
865,6 MHz to 868 MHz	Backscatter	500 mW_{ERP}	Ultra high frequency.
902 MHz to 928 MHz	Backscatter	4 W_{EIRP}	Ultra high frequency. Spread Spectrum
2,4 GHz to 2,483 GHz	Backscatter	4 W_{EIRP}	Super high frequency. Spread Spectrum
2,446 GHz to 2,454 GHz	Backscatter	0,5 W_{EIRP} outdoor 4 W_{EIRP} indoor	Super high Frequency. Used for RFID and Automatic Vehicle identification
5,725 GHz to 5,875 GHz	Backscatter	4 W North America 500 mW Europe	Super high frequency
Indicated field strength values refer to a distance of 10 m.			

Table B.6 – Frequency allocations of TETRA system (in Europe)

Emergency systems			Civil systems		
Number	Frequency pair (MHz)		Number	Frequency pair (MHz)	
	Band 1	Band 2		Band 1	Band 2
1	380 to 383	390 to 393	1	410 to 420	420 to 430
2	383 to 385	393 to 395	2	870 to 876	915 to 921
			3	450 to 460	460 to 470
			4	385 to 390	395 to 399,9

Table B.5 and Table B.6 may be used as references for Table 33 to Table 39 in 6.2.3.2.

Table B.7 – Amateur radiofrequencies (ITU regions 1 to 3)

Frequency band	Frequency unit	Power (PEP) W
135,7 to 137,8	kHz	1 W ERP
1,800 to 2,000	MHz	1 500
3,500 to 4,000	MHz	1 500
5,330 5 5,366 5 5,371 5 5,403 5	MHz MHz MHz MHz	50 50 50 50
7,000 to 7,300	MHz	1 500
10,100 to 10,1573	MHz	1 500
14,000 to 14,350	MHz	1 500
18,068 to 18,168	MHz	1 500
21,000 to 21,450	MHz	1 500
24,890 to 24,990	MHz	1 500
28 to 29,7	MHz	1 500
50 to 54	MHz	1 500
144 to 148	MHz	1 500
219 to 220	MHz	1 500
222 to 225	MHz	1 500
420 to 450	MHz	1 500
902 to 928	MHz	1 500
1,240 to 1,300	GHz	1 500
2,300 to 2,450	GHz	1 500
3,300 to 3,500	GHz	1 500
5,650 to 5,925	GHz	1 500
10,00 to 10,50	GHz	1 500
24,00 to 24,25	GHz	1 500
47,00 to 47,20	GHz	1 500
75,50 to 81,50	GHz	1 500
122,25 to 123,00	GHz	1 500
134,00 to 141,00	GHz	1 500
241,00 to 250,00	GHz	1 500
> 275,00	GHz	1 500

Formulae (B.1) to (B.9) give some technical background for the determination of field strength levels in the various tables of 6.2, taking into account far- and near-field conditions. The electric fields given in the tables of 6.2 are calculated by the following method considering the near-field condition.

Near-field terms should also be assumed when distance $d < \lambda/2\pi$. A dipole antenna or dipole-like antenna is used as the transmitting antenna for a cellular phone. The electric field strength of a dipole antenna is given as

$$E = \frac{\eta_0 Ia}{2\lambda d}\sqrt{1-\left(\frac{\lambda}{2\pi d}\right)^2+\left(\frac{\lambda}{2\pi d}\right)^4}, \qquad \text{(B.1)}$$

where

η_0 is the wave impedance of free space in ohm (Ω),

I is the dipole current in ampere (A),

a is the length of dipole elements in meter (m),

λ is the wavelength in meter (m).

When $d > \lambda/2\pi$ in the far-field condition, the electric field in Formula (B.1) is obtained from:

$$E = \frac{\eta_0 I a}{2\lambda d} \tag{B.2}$$

Meanwhile, the electric field in the far-field condition is given as

$$E = \frac{\sqrt{30 P G_{\mathrm{a}}}}{d} \tag{B.3}$$

where

P is the input power (ERP) to the transmitting antenna in watt (W),

G_{a} is the absolute gain of the antenna.

From Formulae (B.2) and (B.3), the electric field E in Formula (B.1) is rewritten as

$$E = \frac{\sqrt{30 P G_{\mathrm{a}}}}{d} \sqrt{1 - \left(\frac{\lambda}{2\pi d}\right)^2 + \left(\frac{\lambda}{2\pi d}\right)^4} . \tag{B.4}$$

When $d < \lambda/2\pi$ in the near-field condition, the electric field E in Formula (B.4) is obtained from:

$$E = \frac{\lambda^2 \sqrt{30 P G_{\mathrm{a}}}}{4\pi^2 d^3} \tag{B.5}$$

The distances in the tables in 6.2 are calculated with the gain, G_{a}, assumed to be 1,64 (2,15 dB) which is an absolute gain of a half-wavelength dipole antenna. Each electric field is calculated from Formula (B.4).

The magnetic fields given in Table 39 and Table 40 in 6.2.3.3 are calculated by the following method considering the near-field condition.

For the frequencies below 135 kHz, at 13,56 MHz and at 27 MHz, the near-field condition is assumed. The near-field threshold distance, d, is given as $d < \lambda/2\pi$. A loop antenna is used as the transmitting antenna for an RFID transmitter at these frequencies. The electric and magnetic fields of a loop antenna are given as

$$E = \frac{\eta_0 \pi I S}{\lambda^2 d} \sqrt{1 + \left(\frac{\lambda}{2\pi d}\right)^2} \tag{B.6}$$

$$H = \frac{\pi I S}{\lambda^2 d} \sqrt{1 - \left(\frac{\lambda}{2\pi d}\right)^2 + \left(\frac{\lambda}{2\pi d}\right)^4} , \tag{B.7}$$

where

η_0 is the wave impedance of free space in ohm (Ω),

I is the loop current in ampere (A),

S is equal to $n^2 S_0$, where n and S_0 are the number of turns and loop area in square metres (m^2), respectively

λ is the wavelength in meter (m).

The distances, d, in the tables in 6.2 are calculated with the parameters I and S, respectively. When $\lambda > 2\pi d$, the electric and magnetic fields are derived from Formulae (B.6) and (B.7):

$$E = \frac{\eta_0 IS}{2\lambda d^2} \quad \text{(B.8)}$$

$$H = \frac{IS}{4\pi d^3}. \quad \text{(B.9)}$$

The wave impedance is smaller than 120 π in the near-field condition. Formula (B.9) shows that the magnetic field in near field is independent from wavelength (frequency).

Annex C
(informative)

Review of the historical assignment of radiated disturbance degrees

C.1 General

Edition 1 of this document considered the five different radiated disturbance degrees that are presented in Table C.1. The disturbance degrees were obtained from analysis of the probability, p, with which a piece of electronic equipment that was randomly located about a fixed broadcast antenna would experience a radiated electromagnetic field level equal to or less than a given value, E_L. Decade steps of probability values were taken and the values of E_L presented in Table C.1 were obtained.

Table C.1 – Radiated disturbance degrees defined in Edition 1

Disturbance degree	E_L (V/m)
1	0,3
2	1
3	3
4	10
5	30

During the preparation of Edition 2 of this document, the analysis documented within Annex B of Edition 1 was reviewed. The conclusion of the review was that the formula used within the Edition 1 to obtain the disturbance degrees presented in Table C.1 was incorrect. The corrected formulae are presented here. During the preparation of Edition 2 of this document, it was decided to retain the original disturbance degrees for the purposes of historical continuity.

C.2 Revised analysis of radiated disturbance degrees

C.2.1 Analysis

As a start, an idealised, isotropic transmitting antenna is assumed. The radiated electric field, E, about such an antenna may be described by the following formula:

$$E = \frac{\sqrt{30P}}{d} \quad \text{(C.1)}$$

where

P is the total power radiated by the antenna,

d is the radial separation between the antenna and the point of observation.

Next an annulus centred on the idealised, isotropic transmitting antenna is considered, with internal radius r and width, w. See Figure C.1.

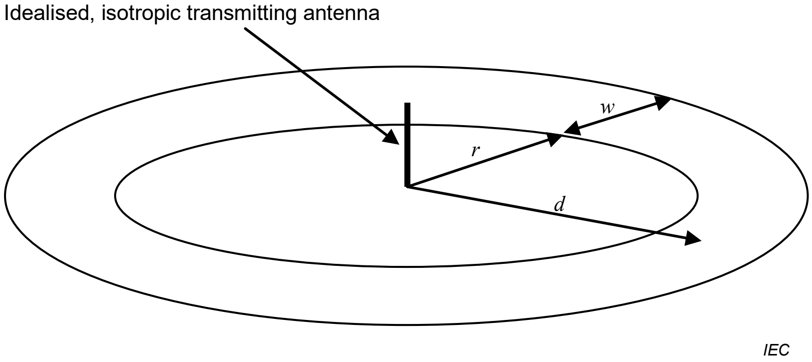


Figure C.1 – Problem geometry

At the inner boundary to the annulus, $d=r$ and so $E(d) = E(r)$, which can also be written as E_i.

At the outer boundary to the annulus, $d=(r+w)$ and so $E(d)=E(r+w)$, which can also be written as E_o.

If one considers that the point of observation may be situated anywhere within the annulus, then it follows that:

$$r \le d \le (r+w) \tag{C.2}$$

This in turn means that the radiated electric field within the annulus satisfies the following condition:

$$E_o \le E(d) \le E_i \tag{C.3}$$

So, within the annulus, when d satisfies the condition presented as Formula (C.2), the radiated electric field level varies between the limits presented as Formula (C.3) in accordance with the formula presented as Formula (C.1).

The probability that the radiated electric field will not exceed a specified level, denoted as E_L and written as $p(E \le E_L)$, may be written as follows (being obtained from the geometric arguments presented in C.2.2.2):

$$p(E \le E_L) = \frac{E_i^2\left(E_L^2 - E_o^2\right)}{E_L^2\left(E_i^2 - E_o^2\right)} \tag{C.4}$$

Note that when $E_L = E_o$, $p(E \le E_o) = 0$. This means that at no point within the annulus will the radiated electric field level be less than or equal to the radiated field level at the outer boundary, E_o; for the electric field to be less than this level, the point of interest will need to be located outside the outer boundary.

Similarly, when $E_L = E_i$, $p(E \le E_i) = 1$. This means that at all points within the annulus, the radiated electric field level will be less than or equal to the radiated field level at the inner boundary E_i.

If both the values of E_i and E_o and the probability threshold are known, it is possible to obtain values of E_L associated with this known probability threshold using the following expression:

$$E_L = \frac{E_o}{\sqrt{1 + p(E \le E_L)(\beta^2 - 1)}} \tag{C.5}$$

where

$$\beta = \frac{E_o}{E_i} \tag{C.6}$$

Now, if $E_i >> E_o$, then $\beta \to 0$, meaning that $(\beta^2 - 1) \to -1$. Hence it is possible to write Formula (C.5) as follows:

$$E_L = \frac{E_o}{\sqrt{1 - p(E \le E_L)}} \tag{C.7}$$

Formula (C.7) is to be compared with the formula presented in Annex B of Edition 1:

$$E_L = \frac{E_o}{\sqrt{p(E \le E_L)}}$$

C.2.2 Detailed derivations

C.2.2.1 General

Subclause C.2.2 presents the detailed mathematical arguments mentioned in C.2.1.

C.2.2.2 Derivation of Formula (C.4)

It can be assumed that the point of observation is randomly located within the annulus, that is, that the point of observation can be located at any point within the annulus and that all points are equally likely to occur. A result of this is that the value of d for the point of observation is similarly randomly located, that is, the separation between the point of observation and the idealised, isotropic transmitting antenna may adopt any value within the range presented as Formula (C.2) and is equally likely to adopt any such value.

It is noted that an isotropic radiating antenna is assumed here. Hence, at a given distance from the antenna d_L, there exists a circular contour of length $2\pi d_L$ along the length of which the radiated electric field is at a constant level, E_L.

It is also noted that as the distance d_L increases, the associated electric field level E_L, decreases. Hence, the radiated electric field will not exceed a given level, i.e. $E \le E_L$, for as long as d exists within the following range:

$$d_L \le d \le (r + w) \tag{C.8}$$

i.e. as long as d exists between the value d_L and the outer edge of the annulus (located at $d = r + w$).

Given that the location of our point, P, is noted to be randomly located within the area of the annulus, the probability that the radiated electric field, E, will not exceed a given level, E_L, is the ratio of the area of the annulus that satisfies Formula (C.8) and the total area of the annulus itself:

$$p(E \le E_L) = \frac{\pi\left((r+w)^2 - d_L^2\right)}{\pi\left((r+w)^2 - r^2\right)} = \frac{\left((r+w)^2 - d_L^2\right)}{\left((r+w)^2 - r^2\right)} \quad \text{(C.9)}$$

Given that, from Formula (C.2), it is possible to write:

$$d_L = \frac{7\sqrt{P}}{E_L} \qquad (r+w) = \frac{7\sqrt{P}}{E_o} \qquad r = \frac{7\sqrt{P}}{E_i}$$

it is possible to rewrite Formula (C.9) as follows:

$$p(E \le E_L) = \frac{\left(\left(\frac{7\sqrt{P}}{E_o}\right)^2 - \left(\frac{7\sqrt{P}}{E_L}\right)^2\right)}{\left(\left(\frac{7\sqrt{P}}{E_o}\right)^2 - \left(\frac{7\sqrt{P}}{E_i}\right)^2\right)}$$

$$\Leftrightarrow p(E \le E_L) = \frac{\left(\frac{49P}{E_o^2} - \frac{49P}{E_L^2}\right)}{\left(\frac{49P}{E_o^2} - \frac{49P}{E_i^2}\right)}$$

$$\Leftrightarrow p(E \le E_L) = \frac{49P\left(\frac{1}{E_o^2} - \frac{1}{E_L^2}\right)}{49P\left(\frac{1}{E_o^2} - \frac{1}{E_i^2}\right)}$$

$$\Leftrightarrow p(E \le E_L) = \frac{\left(\frac{E_L^2 - E_o^2}{E_o^2 E_L^2}\right)}{\left(\frac{E_i^2 - E_o^2}{E_o^2 E_i^2}\right)}$$

$$\Leftrightarrow p(E \le E_L) = \left(\frac{E_L^2 - E_o^2}{E_o^2 E_L^2}\right)\left(\frac{E_o^2 E_i^2}{E_i^2 - E_o^2}\right)$$

$$\Leftrightarrow p(E \le E_L) = \left(\frac{E_L^2 - E_o^2}{E_L^2}\right)\left(\frac{E_i^2}{E_i^2 - E_o^2}\right)$$

$$\Leftrightarrow p(E \leq E_\text{L}) = \frac{E_\text{i}^{2}\left(E_\text{L}^{2} - E_\text{o}^{2}\right)}{E_\text{L}^{2}\left(E_\text{i}^{2} - E_\text{o}^{2}\right)} \tag{C.10}$$

Formula (C.10) therefore presents the relationship between the probability that the radiated electric field will not exceed a given level, E_L, with the value of E_L and the constants E_o and E_i.

C.2.2.3 Derivation of Formula (C.5)

When the probability factor is known, the threshold electric field value, E_L may be found from rearranging Formula (C.10) as follows:

$$p(E \leq E_\text{L}) = \frac{E_\text{i}^{2}\left(E_\text{L}^{2} - E_\text{o}^{2}\right)}{E_\text{L}^{2}\left(E_\text{i}^{2} - E_\text{o}^{2}\right)}$$

$$\Leftrightarrow p(E \leq E_\text{L}) \frac{\left(E_\text{i}^{2} - E_\text{o}^{2}\right)}{E_\text{i}^{2}} = \frac{\left(E_\text{L}^{2} - E_\text{o}^{2}\right)}{E_\text{L}^{2}}$$

$$\Leftrightarrow p(E \leq E_\text{L}) \left(\frac{E_\text{i}^{2}}{E_\text{i}^{2}} - \frac{E_\text{o}^{2}}{E_\text{i}^{2}}\right) = \left(\frac{E_\text{L}^{2}}{E_\text{L}^{2}} - \frac{E_\text{o}^{2}}{E_\text{L}^{2}}\right)$$

$$\Leftrightarrow p(E \leq E_\text{L}) \left(1 - \frac{E_\text{o}^{2}}{E_\text{i}^{2}}\right) = \left(1 - \frac{E_\text{o}^{2}}{E_\text{L}^{2}}\right)$$

writing

$$\beta = \frac{E_\text{o}}{E_\text{i}} \tag{C.11}$$

Then it is possible to write

$$\Leftrightarrow \left(1 - \beta^{2}\right) p(E \leq E_\text{L}) = \left(1 - \frac{E_\text{o}^{2}}{E_\text{L}^{2}}\right)$$

$$\Leftrightarrow \left(1 - \beta^{2}\right) p(E \leq E_\text{L}) - \left(1 - \frac{E_\text{o}^{2}}{E_\text{L}^{2}}\right) = 0$$

$$\Leftrightarrow \left(1 - \beta^{2}\right) p(E \leq E_\text{L}) + \frac{E_\text{o}^{2}}{E_\text{L}^{2}} - 1 = 0$$

$$\Leftrightarrow \frac{E_\text{o}^{2}}{E_\text{L}^{2}} = 1 - \left(1 - \beta^{2}\right) p(E \leq E_\text{L})$$

$$\Leftrightarrow \frac{E_{\mathrm{o}}^{\;2}}{E_{\mathrm{L}}^{\;2}} = 1 + \left(\beta^{2} - 1\right) p(E \le E_{\mathrm{L}})$$

$$\Leftrightarrow E_{\mathrm{L}}^{\;2} = \frac{E_{\mathrm{o}}^{\;2}}{1 + \left(\beta^{2} - 1\right) p(E \le E_{\mathrm{L}})}$$

$$\Leftrightarrow E_{\mathrm{L}} = \sqrt{\frac{E_{\mathrm{o}}^{\;2}}{1 + \left(\beta^{2} - 1\right) p(E \le E_{\mathrm{L}})}}$$

$$\Leftrightarrow E_{\mathrm{L}} = \frac{E_{\mathrm{o}}}{\sqrt{1 + \left(\beta^{2} - 1\right) p(E \le E_{\mathrm{L}})}} \qquad \text{(C.12)}$$

Given the expression for β presented earlier as Formula (C.11), it is possible to write

$$E_{\mathrm{o}} = \beta E_{\mathrm{i}}$$

And hence to rewrite Formula (C.12) as follows:

$$E_{\mathrm{L}} = \frac{\beta E_{\mathrm{i}}}{\sqrt{1 + \left(\beta^{2} - 1\right) p\left(E \le E_{\mathrm{L}}\right)}} \qquad \text{(C.13)}$$

Annex D
(informative)

Radiated pulsed disturbances

There is a wide variety of pulsed radiated disturbances, although in this document the interest is on understanding the most common types. The primary causes of pulse radiated disturbances include:

– lightning discharges;
– static electricity discharges;
– on- and off-load switching in low-, medium- and high-voltage power networks;
– RADAR.

Several typical pulsed waveforms are shown below. Figure D.1 is an example of a measured electric field and its derivative for a lightning discharge at a distance of 30 m. Note that the electric field waveform includes the slow decreasing portion of the field created by the lightning leader, followed by the sharp increase due to the return stroke. The return stroke is responsible for the derivative waveform shown in the right portion of Figure D.1 with a significantly shorter time scale. Figure D.2 is an example of an electric field, and Figure D.3 is the magnetic field at 0,1 m, both from a discharge of static electricity (see Table 41 and Table 43, respectively, for additional level values).

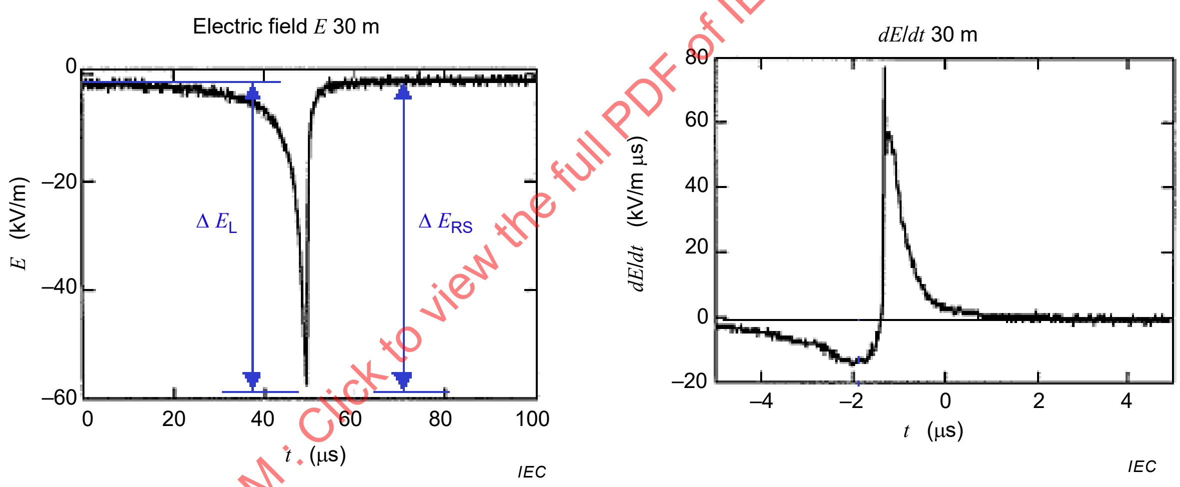


Figure D.1 – Measured electric field and electric field derivative from a cloud-to-ground lightning strike measured at a distance of 30 m

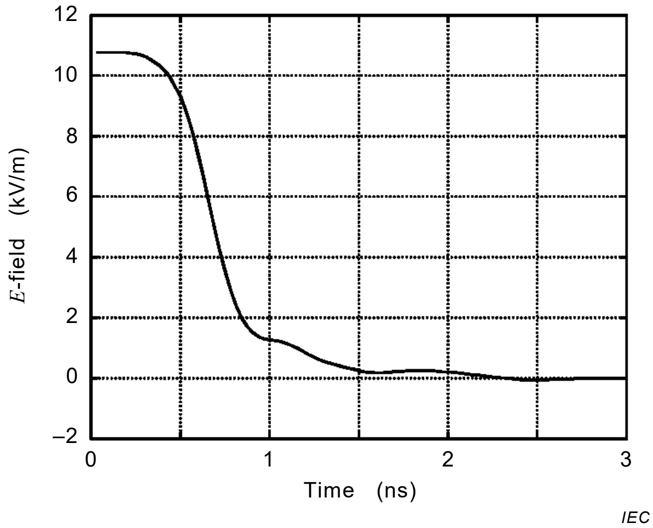


Figure D.2 – Measured electric field from an electrostatic discharge event at a distance of 0,1 m

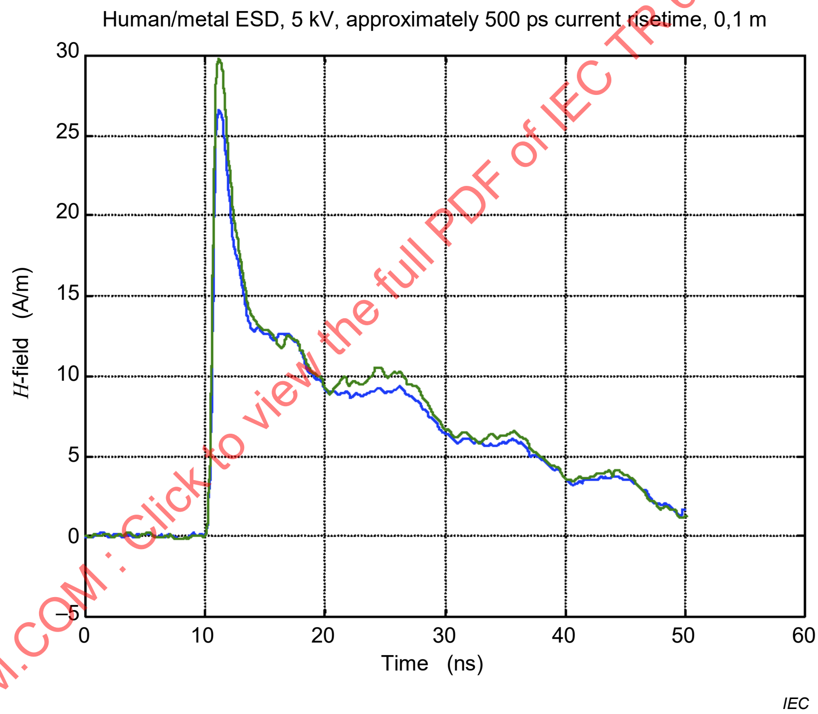


Figure D.3 – Measured magnetic field (two measurements) from an electrostatic discharge event at a distance of 0,1 m

For switching events primarily found in power system substations, high intensity electromagnetic pulsed fields are generated. While these fields decrease with range from the switching location, they couple efficiently to cables in substations or industrial facilities near industrial substations and create conducted transients that may impact control systems. Figure D.4 is an example of a measured electric field from the reconnection of a disconnected switch in a 500 kV substation.

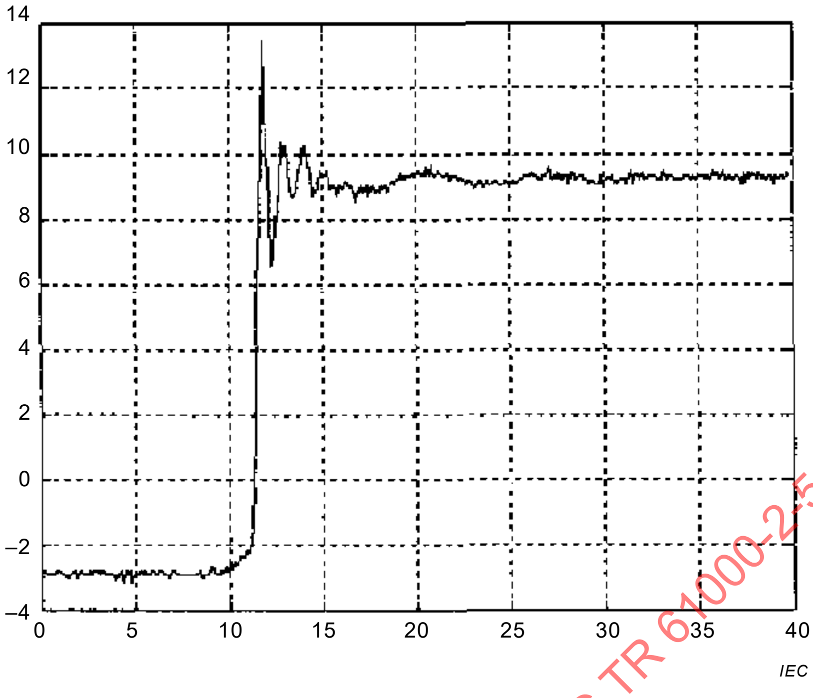


Figure D.4 – Measured electric field in kV/m versus time in µs in a 500 kV power substation

For RADAR systems, often found near airports or on-board ships, the electromagnetic fields produced can be very high, mainly due to the high power involved. Table C.1 provides information concerning the names of the bands, the frequency range involved and the type of service provided by the RADAR. Table C.2 provides the power levels, frequency bands and the types of modulations used by particular radars. These power levels can be used to estimate the electric and magnetic field levels that may exist as a function of range from each RADAR system (see for example Table 42).

The most important parameters for pulses are: the amplitude, the derivative, the duration, the energy content, the repetition rate (number of pulses occurring in a given time frame), and the rate of occurrence (number of times that a particular phenomenon occurs per year). The latter is considered in the statistical approach.

Table D.1 – Data regarding RADAR systems

Old band name Germany	Band name EU	Band name US	Frequency	Type of service
	C	L	0,5 GHz to 1 GHz	Long distance air traffic control
L	D	L / S	1 GHz to 2 GHz	Long distance air traffic control
S S	E F	S S / C	2 GHz to 3 GHz 3 GHz to 4 GHz	Medium range air traffic control Terminal traffic control Long distance weather RADAR
C X	G H	C X	4 GHz to 6 GHz 6 GHz to 8 GHz	Medium range air traffic control Airborne weather RADAR
X X	I J	X / K K	8 GHz to 10 GHz 10 GHz to 12 GHz	Short distance air traffic control Ship / navy RADAR Airborne surface map RADAR, Ground traffic control (police)
Ku	J	K	12 GHz to 18 GHz	Airborne high resolution surface mapping by RADAR Ground traffic control (police)
K K	J K	K K	18 GHz to 20 GHz 20 GHz to 27 GHz	Not used because of high attenuation (water vapour)
Ka	K	K / Q	27 GHz to 40 GHz	Airborne high resolution surface mapping by RADAR Runway traffic control (airport) Ground traffic control (police)
	L	Q / V / W	40 GHz to 60 GHz	Used but not assigned to civil services
	M	W	60 GHz to 100 GHz	Car born RADAR (adaptive cruise control)

Table D.2– Examples for civil RADAR systems

Band	Frequency	Power (P_{EIRP})	Modulation	Type of service
	0,9 GHz to 1,2 GHz	10 kW	Pulse	Flight navigation (DME/TECAN)
D		2 MW	Pulse	"Selenia" ALE 3x5 L Air traffic control (airport)
	1,24 GHz to 1,4 GHz	10 kW - 2,5 MW	Pulse	Air traffic control (ARSR)
	1,250 GHz to 1,350 GHz	2,5 MW	Pulse (2µs, 3,50 Hz to 480 Hz)	SRE-M6/7
	1,250 GHz to 1,350 GHz	75 kW	Pulse (0,6µs, 12µ, 250µs)	SRE-M8
E		2,5 MW	Pulse (2,1 µs / 1 050 Hz)	ASR-910
E	2,7 GHz to 2,9 GHz	22 kW	Pulse (1 µs, 55 µs)	ASR-12
E	2,7 GHz to 2,9 GHz	25 kW	Pulse (1 µs, 2,45 µs)	ASR-E
	2,7 GHz to 2,9 GHz	15 / 28 kW	Pulse (1 µs, 75 µs)	STAR -2000
S	2,7 GHz to 2,9 GHz	24 kW	Pulse (10 µs, 100 µs, 800 Hz)	ATCR-33S DPC
E		650 kW	Pulse (0,85 µs)	ATC-Radar S-511
	2,7 GHz to 2,9 GHz	25 kW	Pulse	(DASR) ASR-11
	2,7 GHz to 2,9 GHz	1 MW	Pulse (325 Hz to 1200 Hz)	ASR-9
	2,7 GHz to 3,4 GHz	500 kW	Pulse	Air traffic control (airport)
	5,255 GHz to 5,850 GHz	50 kW	Pulse	Air born RADAR, weather RADAR
	9,0 GHz to 9,2 GHz	10 kW	Pulse	Ground traffic control (airport, PAR)
X	9,170 GHz, 9,375 GHz, 9,410 GHz, 9,438 GHz, 9,490 GHz	30 kW	Pulse (40 ns, 800 Hz to 8 000 Hz)	Scanter 2001 Ground traffic control (airport)
	9,3 GHz to 9,5 GHz	10 kW	Pulse	Ground traffic control (airport); weather RADAR'; pilot RADAR (ship)
	9,37 GHz	17 kW	Pulse (60 ns, 8192 Hz)	NOVA 9004 Ground traffic control (airport, PAR)
	9,9 GHz 10,525 GHz			Ground traffic control (police)
X	15,7 GHz to 16,7 GHz		Pulse (40 ns)	ASDE Ground traffic control (airport, PAR)
	13,45 GHz			Ground traffic control (police)
	24,125 GHz	500 mW (0,5 mW + 30dB antenna gain)		Ground traffic control (police)
	34,0 GHz to 34,3 GHz			Ground traffic control (police)
	77 GHz	0,223 W to 316 W	FM / CW	Car borne RADAR (adaptive cruise control)

Annex E
(informative)

Power line telecommunications (PLT)

Power line telecommunications (PLT), power line communications (PLC) and broadband over power line (BPL) are different terms for the same type of systems used to deliver high speed data services over existing electricity supply cables. The term PLT ~~will be~~ is used in this document.

The PLT concept is similar to the DSL concept because the power cable is used on a secondary basis like the phone cables used by DSL.

Due to the fact that power line cables are used to transmit high frequency signal in the frequency range between ~~2 MHz – 30 MHz, a wide frequency band is disturbed by the leaky emission of these cables~~ 9 kHz to 148,5 kHz (CENELEC-PLC), 150 kHz to 500 kHz (FCC-band PLC) and 1,606 5 MHz to 87,5 MHz, the broadband radiated and conducted emissions can be radiated by the cables that are connected with PLT modems.

Electricity supply cables are not designed, screened or balanced for high frequency use ~~and even when buried below ground they can radiate significant emissions and have the potential to interfere with the reception of radio communication services including short wave broadcasts~~; by contrast, DSL is transmitted by telephone cables that are designed as communication cables. The telephone cable is typically twist-paired and balanced. The LCL (longitudinal conversion loss) of the telephone cable is usually 60 dB or more. On the other hand, the LCL of power cables is much lower than that of the telephone cables, for example 16 dB because the power cables in-house usually have many branchings and unbalanced cablings to install the plugs for home electrical appliances. The unbalance of the cables generates the common mode currents, and an emission by the common mode currents raises the interference to the communications and broadcasting services in the short-wave frequency band.

The radiated electromagnetic fields caused by PLT systems normally do not have the potential to ~~disturb the function of~~ prevent equipment for household or industrial use from properly functioning because the field strength could be expected to be ~1 V/m. For conducted emissions which are very close to a PLT system, levels up to several V_{pp} could be expected and have to be taken into account. PLT systems may normally have a disturbance potential at the same level as other electrical equipment that meets the requirements of product committees.

PLT systems are also used for communications at frequencies below 150 kHz, especially for Smart Grid applications. In particular some countries are using PLT to communicate with their advanced metering infrastructure (AMI). In addition, some electric vehicle chargers and photovoltaic power generation systems use PLT systems to control the systems and to exchange data. These PLT systems may create disturbances or may be disturbed themselves depending on their locations, the signal types and the ambient conditions.

1) Europe

In Europe two different types of PLT systems are used:

- Access PLT systems are used between an electricity substation and the PLT customers connected to it. A typical 500 kVA substation can serve up to about 200 electricity users, situated within a 200 m radius, with the potential PLT customer base being a small percentage of these. To serve these customers with broadband internet access, each PLT-enabled electricity substation shall be connected to an ~~ISP~~ internet service provider via a dedicated high capacity link.
- In-house PLT systems are used for home networking purposes. All types of data (audio, video, data) are transmitted between different users inside a house or flat. Different types

of PLT systems (modem chipsets, modulation types, frequency bands) cannot be used in close proximity due to the fact that at this ~~moment~~ time no standardisation has been done between different manufacturers.

2) US

In the US the situation is similar to Europe, but some access PLT networks are configured differently. This is because the electricity distribution network is largely based on medium-voltage overhead lines with small capacity pole mounted transformers, each supplying a few customers. This has led to the development of PLT equipment that operates over the MV network.

3) Japan

Power line telecommunications are used only for home networking (limitation of indoor use) in Japan. The Japanese radio law prohibits the use of PLT for direct access to the customer to avoid adverse electromagnetic radiation. Most power distribution lines are laid as overhead wires in Japan. Communication lines and power distribution lines are often installed on the same power poles.

4) Korea

In Korea, PLT is used for home networking and industrial systems. It is also used for smart grid applications. Korean law regulates the frequency range and the level of PLT to protect other communications and systems. It is strictly prohibited to use some of the frequency ranges so as not to disturb national disaster/distress communications.

Annex F
(informative)

Distributed generation

Distributed generation produces electric power at many diverse locations including close to the load. Compared with the conventional power plants, distributed generators often use photovoltaic generation systems, wind turbines, fuel cells, electrical energy storage systems, etc. In order to maintain a stable voltage and frequency, they also use inverters and/or converters. These often result in increased levels of harmonics and disturbances which need to be considered.

Figure F.1 shows an example of the voltages produced by an electrical energy storage system, and Figure F.2 shows an example of the voltage produced by a photovoltaic inverter.

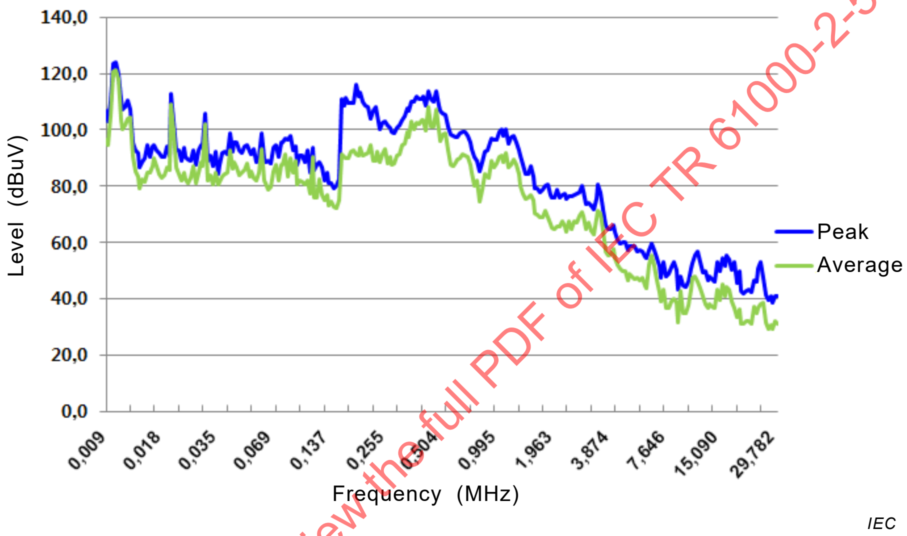


Figure F.1 – Example of disturbance voltages for electrical energy storage system (140 kVA) in situ with the frequency range of 9 kHz to about 30 MHz

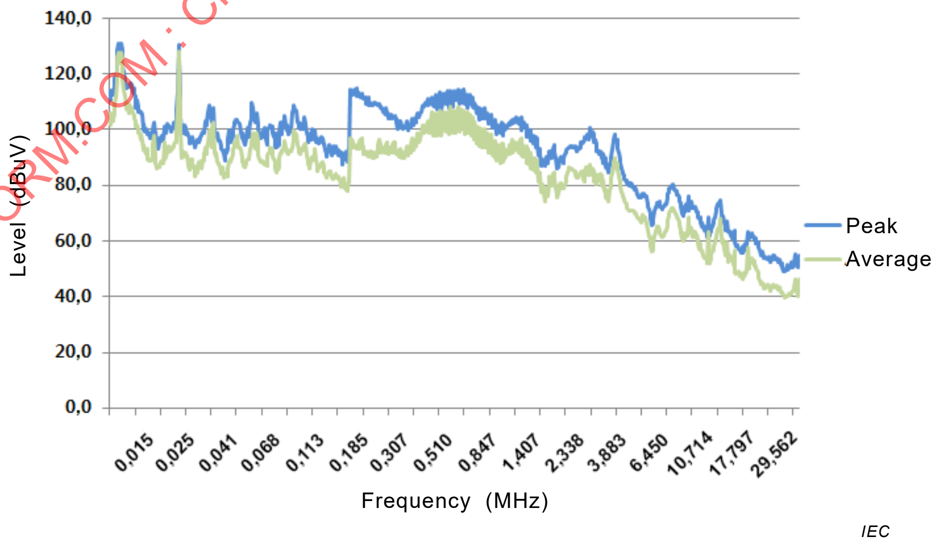


Figure F.2 – Example of disturbance voltages from a photovoltaic inverter (21 kW) in situ with the frequency range of 9 kHz to about 30 MHz

NOTE The sharp increases at 150 kHz in both figures is due to a change in the resolution bandwidth.

Annex G
(informative)

Information on disturbance and compatibility levels available in documents of the IEC 61000-2 series

Though this document is intended to give a comprehensive description of all relevant electromagnetic phenomena to be expected in various types of electromagnetic environments, it does not contain detailed information about all of those phenomena especially in the low frequency range below 9 kHz. However, such information is available in other parts of the IEC 61000-2 series and this document makes use of that information by making references to the IEC 61000-2 series or by copying the relevant data into this document.

Table G.1 gives an overview of documents of the IEC 61000-2 series which deal with the description of electromagnetic environments and describes the phenomena and the frequency ranges considered in those documents. As can be seen from the table, most documents deal with low frequency conducted phenomena on the one hand, and with the phenomena of HPEM/HEMP on the other.

Table G.1 – Overview of the IEC 61000-2 series

Publication	Title and short description	Electromagnetic phenomena	Frequency range
IEC TR 61000-2-1	**Electromagnetic compatibility (EMC) – Part 2: Environment – Section 1: Description of the environment – Electromagnetic environment for low-frequency conducted disturbances and signalling in public power supply systems** This report is concerned with conducted disturbances in the frequency range up to 10 kHz with an extension to higher frequencies for mains signalling systems. Some general information on sources of conducted phenomena is given and some formulas for determining amplitudes of those phenomena are presented.	Conducted disturbances: • harmonics • inter-harmonics • voltage fluctuations • voltage dips and short supply interruptions • voltage unbalance • mains signalling (< 150 kHz) • power frequency variation	< 10 kHz
IEC 61000-2-2	**Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems** This standard gives compatibility levels for public low-voltage AC distribution systems having a nominal voltage up to 420 V, single-phase or 690 V, three-phase and a nominal frequency of 50 Hz or 60 Hz.	Conducted disturbances: • harmonics • inter-harmonics • voltage unbalance • power frequency variation • mains signalling (< 150 kHz)	< 9 kHz
IEC TR 61000-2-3	**Electromagnetic compatibility (EMC) – Part 2: Environment – Section 3: Description of the environment – Radiated and non-network-frequency-related conducted phenomena** Report about general concepts of • sources, coupling mechanisms and susceptors • units and decibels • electromagnetic fields, antenna theory, corona effects • intentional and unintentional radiators • electrostatic discharge • power frequency fields • switching transients • examples of emission spectra of various types of equipment	Radiated phenomena Conducted phenomena, non-network-frequency related	
IEC 61000-2-4	**Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances** This standard applies to low-voltage and medium-voltage AC power supply at 50/60 Hz associated with industrial and non-public networks.	Conducted disturbances: • harmonics • inter-harmonics • voltage fluctuations • voltage unbalance • mains signalling (< 150 kHz) • power frequency variation	< 9 kHz

Publication	Title and short description	Electromagnetic phenomena	Frequency range
IEC TR 61000-2-6	**Electromagnetic compatibility (EMC) – Part 2: Environment – Section 6: Assessment of the emission levels in the power supply of industrial plants as regards low-frequency conducted disturbances** This report recommends procedures to assess the disturbance levels produced by the emission of the devices, equipment and systems installed in non-public networks in industrial environment; it applies to low and medium AC non-public supply at 50/60 Hz.	Conducted disturbances: • harmonics • inter-harmonics • voltage fluctuations • voltage unbalance	< 9 kHz
IEC TR 61000-2-7	**Electromagnetic compatibility (EMC) – Part 2: Environment – Section 7: Low frequency magnetic fields in various environments** This report gives information about low frequency magnetic fields to be expected in various environments. Considered sources are power supply systems (AC and DC), traction and welding systems.	Low frequency magnetic fields	DC, Power frequency, < 10 kHz
IEC TR 61000-2-8	**Electromagnetic compatibility (EMC) – Part 2-8: Environment – Voltage dips and short interruptions on public electric power supply systems with statistical measurement results** This report describes the electromagnetic disturbance phenomena of voltage dips and short interruptions in terms of their sources, effects, remedial measures, methods of measurement, and measurement results. It applies to public low-voltage power supply networks.	Voltage dips and short interruptions	
IEC 61000-2-9	**Electromagnetic compatibility (EMC) – Part 2: Environment – Section 9: Description of HEMP environment – Radiated disturbance** This part describes the radiated electromagnetic pulse fields created by a high-altitude nuclear detonation reaching the Earth's surface. Three specific pulses are provided in the time domain for civil applications to allow critical infrastructures to define immunity requirements for equipment and systems.	Radiated pulsed fields from high altitude nuclear detonations. Variations due to location on the Earth and for shallow buried locations are provided.	1 mHz < f < 1 GHz
IEC 61000-2-10	**Electromagnetic compatibility (EMC) – Part 2-10:Environment – Description of HEMP environment – Conducted disturbance** This part describes the conducted electromagnetic pulse fields induced by the radiated fields from a high-altitude nuclear detonation (described in IEC 61000-2-9) on metallic lines, such as data cables or power lines, external and internal to installations, and external antennas.	Conducted voltage and current pulses are described for power lines external to installations, for cables inside of installations and for external antennas of different types.	1 mHz < f < 1 GHz
IEC 61000-2-11	**Electromagnetic compatibility (EMC) – Part 2-11: Environment – Classification of HEMP environments** This part describes the classification of the HEMP radiated and conducted environments as a function of the location of equipment either external to or within different types of shielded installations. The purpose of this classification is to support the definition of immunity test levels for equipment as a function of their location.	Classes are defined for both the radiated and conducted pulsed HEMP environment as a function of the amount of protection in an installation. The presence of lightning protection is also considered.	1 kHz < f < 1 GHz

Publication	Title and short description	Electromagnetic phenomena	Frequency range
IEC 61000-2-12	**Electromagnetic compatibility (EMC) –Part 2-12: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public medium-voltage power supply systems** This part is concerned with conducted disturbances in the frequency range from 0 kHz to 9 kHz signalling systems. It gives compatibility levels for public medium-voltage AC distribution systems with a nominal voltage between 1 kV and 35 kV.	Conducted disturbances: • harmonics • voltage fluctuations • voltage unbalance • power frequency variation • mains signalling (< 3 kHz)	< 9 kHz
IEC 61000-2-13	**Electromagnetic compatibility (EMC) – Part 2-13: Environment – High-power electromagnetic (HPEM) environments – Radiated and conducted** This part describes the radiated and conducted environments that could be created by any high power electromagnetic field source (over 100 V/m) but with emphasis on the development of electromagnetic weapons by those who wish to create intentional electromagnetic interference (IEMI). Different classes of wideband waveforms are defined along with narrowband threats, and with the consideration of the difficulty in producing these types of threats.	Radiated and conducted environments (which are narrowband or belong to three separate wideband classes) are defined. The peak fields are characterized in terms of the product of "distance × peak field", which allows the consideration of distance to an installation as a major parameter. Both coupled fields and directly injected voltages are also considered.	1 MHz < f < 10 GHz
IEC TR 61000-2-14	**Electromagnetic compatibility (EMC) – Part 2-14: Environment – Overvoltages on public electricity distribution networks** This report gives information on transients in low- and medium-voltage public power supply systems.	Conducted disturbances: • overvoltages • external and internal overvoltages • long, short and very short overvoltages • lightning and switching transients	

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TECHNICAL REPORT

colour inside

BASIC EMC PUBLICATION

Electromagnetic compatibility (EMC) –
Part 2-5: Environment – Description and classification of electromagnetic environments

IEC TR 61000-2-5:2017-01(en)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 2-5: Environment – Description and classification of electromagnetic environments

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 (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.
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The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 61000-2-5, which is a technical report, has been prepared by technical committee 77: Electromagnetic compatibility.

It forms Part 2-5 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This third edition cancels and replaces the second published in 2011. This edition constitutes a technical revision.

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

a) the description of the radiated electromagnetic environment has been updated taking into account recent communication technologies;
b) some conducted phenomena and respective interference sources have been described in more detail.

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

Enquiry draft	Report on voting
77/525A/DTR	77/526/RVC

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

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The reader's attention is drawn to the fact that Annex E lists some "in-some-country" clauses on differing practices regarding a particular electromagnetic phenomenon.

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 "http://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.

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 2-5: Environment – Description and classification of electromagnetic environments

1 Scope

Knowledge of the electromagnetic environment that exists at locations where electrical and electronic equipment and systems are intended to be operated is an essential precondition in the process of achieving electromagnetic compatibility. This knowledge can be obtained by various approaches, including a site survey of an intended location, the technical assessment of the equipment and system, as well as the general literature.

This part of IEC 61000

- introduces the concept of disturbance degrees and defines these for each electromagnetic phenomena,
- classifies into various location classes and describes them by means of attributes,
- provides background information on the different electromagnetic phenomena that may exist within the environment and
- compiles tables of compatibility levels for electromagnetic phenomena that are considered to be relevant for those location classes.

This part of IEC 61000 is intended for guidance for those who are in charge of considering and developing immunity requirements. It also gives basic guidance for the selection of immunity levels. The data are applicable to any item of electrical or electronic equipment, sub-system or system that operates in one of the locations as considered in this document.

NOTE 1 This document considers relevant electromagnetic phenomena when describing and classifying electromagnetic environments (except HEMP and HPEM which are covered in other IEC 61000-2 standards). It makes use of the specification of technologies, of published data and of results from measurements. Not all electromagnetic phenomena considered here are described in detail in this document, but rather in other documents of the IEC 61000-2 series from which the relevant information and data are taken and used in this document. For more detailed information about those phenomena the user is referred to this series. See also Annex F for an overview of the various parts of the IEC 61000-2 series.

NOTE 2 It is noted that immunity requirements and immunity levels determined for items of equipment which are intended to be used at a certain location class are not inevitably bound to the electromagnetic environment present at the location, but also to requirements of the equipment itself and the application in which it is used (e.g. when taking into account requirements regarding availability, reliability or safety). These could lead to more stringent requirements with respect to immunity levels or with respect to applicable performance criteria. These levels can also be established for more general purposes such as in generic and product standards, taking into account statistical and economic aspects as well as common experience in certain application fields.

NOTE 3 Electromagnetic phenomena in general show a broad range of parameters and characteristics and hence cannot be related one-to-one to standardized immunity tests which basically reflect the impact of electromagnetic phenomena by a well described test setup. Nonetheless, this document follows an approach to correlate electromagnetic phenomena and standardized immunity tests up to a certain extent. This might allow users of this document to partly take into account standardized immunity tests such as given for example in IEC 61000-4(all parts), when specifying immunity requirements.

The descriptions of electromagnetic environments in this document are predominantly generic ones, taking into account the characteristics of the location classes under consideration. Hence, it should be kept in mind that there might be locations for which a more specific description is required in order to conclude on immunity requirements applicable for those specific locations.

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 – Chapter 161: Electromagnetic compatibility* (available at www.electropedia.org)

IEC 61000-2-2, *Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*

IEC TR 61000-2-3, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 3: Description of the environment – Radiated and non-network-frequency-related conducted phenomena*

IEC 61000-2-4, *Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances*

IEC TR 61000-2-8, *Electromagnetic compatibility (EMC) – Part 2-8: Environment – Voltage dips and short interruptions on public electric power supply systems with statistical measurement results*

IEC 61000-2-9, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 9: Description of HEMP environment – Radiated disturbance*

IEC 61000-2-12, *Electromagnetic compatibility (EMC) – Part 2-12: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public medium-voltage power supply systems*

IEC 61000-2-13, *Electromagnetic compatibility (EMC) – Part 2-13: Environment – High-power electromagnetic (HPEM) environments – Radiated and conducted*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-9, *Electromagnetic compatibility (EMC) – Part 4-9: Testing and measurement techniques – Impulse magnetic field immunity test*

IEC 61000-4-10, *Electromagnetic compatibility (EMC) – Part 4-10: Testing and measurement techniques – Damped oscillatory magnetic field immunity test*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-12, *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Ring wave immunity test*

IEC 61000-4-13, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests*

IEC 61000-4-14, *Electromagnetic compatibility (EMC) – Part 4-14: Testing and measurement techniques – Voltage fluctuation immunity test for equipment with input current not exceeding 16 A per phase*

IEC 61000-4-16:2015, *Electromagnetic compatibility (EMC) – Part 4-16: Testing and measurement techniques – Test for immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz*

IEC 61000-4-18, *Electromagnetic compatibility (EMC) – Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test*

IEC 61000-4-19, *Electromagnetic compatibility (EMC) – Part 4-19: Testing and measurement techniques – Test for immunity to conducted, differential mode disturbances and signalling in the frequency range 2 kHz to 150 kHz at a.c. power ports*

IEC 61000-4-27, *Electromagnetic compatibility (EMC) – Part 4-27: Testing and measurement techniques – Unbalance, immunity test for equipment with input current not exceeding 16 A per phase*

IEC 61000-4-28, *Electromagnetic compatibility (EMC) – Part 4-28: Testing and measurement techniques – Variation of power frequency, immunity test for equipment with input current not exceeding 16 A per phase*

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
active infeed converter
AIC
self-commutated electronic power converter of all technologies, topologies, voltages and sizes which is connected between the AC power supply network (lines) and usually a stiff DC side (current source or voltage source) and which can convert electric power in both directions (generative or regenerative) and control the reactive power or the power factor

Note 1 to entry: Some active infeed converters can additionally control the harmonics to reduce the distortion of an applied AC voltage or current.

3.1.2
blackout
cutoff of electrical power, especially as a result of shortage, mechanical failure, or overuse by consumers

EXAMPLE A power cut due to a short- or long-term electric power loss in an area.

3.1.3
brownout
reduction or cutback in electric power, especially as a result of shortage, mechanical failure, or overuse by consumers

EXAMPLE Reduction in the voltage of commercially supplied power. It is caused by the failure of the generation, transmission, or distribution system, or deliberately by the power utility when demand exceeds supply. The consumer may or may not notice the difference. In the worst case, damage may result.

3.1.4
burst
sequence of a limited number of distinct pulses or an oscillation of limited duration

[SOURCE: IEC 60050-161:1990, 161-02-07]

3.1.5
burst (in TDMA)
signals transmitted by a terminal in the form of a block of predetermined structure during a time interval allotted to the terminal by a TDMA protocol

[SOURCE: IEC 60050-725:1994, 725-14-15]

3.1.6
characteristic impedance of a medium
wave impedance for a travelling wave in a specific medium

Note 1 to entry: The characteristic impedance of a homogeneous isotropic medium is given by $\eta_t = \sqrt{\dfrac{\mu}{\varepsilon}}$,

where

μ is the permeability of the homogeneous isotropic medium, and

ε is the permittivity of the homogeneous isotropic medium.

[SOURCE: IEC 60050-705:1995, 705-03-23, modified – the formula for characteristic impedance has been simplified.]

3.1.7
commercial, public and light-industrial location
location which exists as areas of the city centre, offices, public transport systems (road/train/underground), and modern business centres containing a concentration of office automation equipment (PCs, fax machines, photocopiers, telephones, etc.), and characterized by the fact that equipment is directly connected to a low-voltage public mains network or connected to a dedicated DC source which is intended to interface between the equipment and the low-voltage mains network

EXAMPLE Examples of commercial, public or light-industrial locations are:

– retail outlets, for example shops, supermarkets;
– business premises, for example offices, banks, hotels, data centers;
– areas of public entertainment, for example cinemas, public bars, dance halls;

– places of worship, for example temples, churches, mosques, synagogues;
– outdoor locations, for example petrol stations, car parks, amusement and sports centers;
– general public locations, for example park, amusement facilities, public offices;
– hospitals, educational institutions, for example schools, universities, colleges;
– public traffic area, railway stations, and public areas of an airport;
– light-industrial locations, for example workshops, laboratories, service centers.

Note 1 to entry: The connection between location and electromagnetic environment is given in 3.1.15.

3.1.8
(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 mmunity 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]

3.1.9
disturbance degree
specified and quantified intensity within a range of disturbance levels corresponding to a particular electromagnetic phenomenon encountered in the environment of interest

3.1.10
disturbance level
amount of magnitude of an electromagnetic disturbance, measured and evaluated in a specified way

3.1.11
earth port
cable port other than signal, control or power port, intended for connection to earth

3.1.12
electric field
constituent of an electromagnetic field which is characterized by the electric field strength E together with the electric flux density D

[SOURCE: IEC 60050-121:1998, 121-11-67]

3.1.13
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 60050-161:1990, 161-01-07, modified – the terms "device" and "equipment" have been added to the definition.]

3.1.14
electromagnetic disturbance
any electromagnetic phenomenon which can degrade the performance of a device, equipment or system, or adversely affect living or inert matter

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

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

3.1.15
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 may need a statistical approach.

Note 2 to entry: It is very important not to confuse the electromagnetic environment and the location itself.

[SOURCE: IEC 60050-161:1990, 161-01-01, modified – a Note 2 to entry has been added.]

3.1.16
electromagnetic field
field, determined by a set of four interrelated vector quantities, that characterizes, together with the electric current density and the volumic electric charge, the electric and magnetic conditions of a material medium or of vacuum

Note 1 to entry: The four interrelated vector quantities, which obey Maxwell Equations, are by convention:

- the electric field strength, E,
- the electric flux density, D,
- the magnetic field strength, H,
- the magnetic flux density, B.

[SOURCE: IEC 60050-121:1998, 121-11-61]

3.1.17
(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]

3.1.18
enclosure port
physical boundary of the equipment, through or on which electromagnetic fields may impinge

3.1.19
far field
region where the angular distribution of the electromagnetic field is independent of distance from the antenna

Note 1 to entry: When the antenna dimensions are smaller than the wavelength, then this region is defined as $d > \lambda / 2\pi$, , where d is the distance from the antenna and λ is the wavelength of the electromagnetic field.

3.1.20
high voltage
HV
1) in a general sense, the set of voltage levels in excess of low voltage
2) in a restrictive sense, the set of upper voltage levels used in power systems for bulk transmission of electricity

[SOURCE: IEC 60050-601:1985, 601-01-27]

3.1.21
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]

3.1.22
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]

3.1.23
industrial location
location characterized by a separate power network, supplied from a high- or medium-voltage transformer, dedicated for the supply of the installation

EXAMPLE Metalworking, pulp and paper, chemical plants, car production, farm building, high-voltage (HV) areas of airports.

Note 1 to entry: Industrial locations can generally be described by the existence of an installation with one or more of the following characteristics:

– items of equipment installed and connected together and working simultaneously;
– significant amount of electrical power is generated, transmitted and/or consumed;
– frequent switching of heavy inductive or capacitive loads;
– high currents and associated magnetic fields;
– presence of industrial, high power scientific and medical (ISM) equipment (for example, welding machines).

The electromagnetic environment at an industrial location is predominantly produced by the equipment and installation present at the location. There are types of industrial locations where some of the electromagnetic phenomena appear in a more severe degree than in other installations.

Note 2 to entry: Industrial locations can be further distinguished, for example into general, process, heavy or power industrial locations.

Note 3 to entry: The connection between location and electromagnetic environment is given in 3.1.15.

[SOURCE: IEC 61000-6-2:2016, 3.7]

3.1.24
infeed converter
self-commutated electronic power converter of all technologies, topologies, voltages and sizes which is connected between the AC power supply network (lines) and usually a stiff DC side (current source or voltage source) and which can convert electric power only in one direction (from AC to DC) and limit harmonic current emissions of the converter and control the power factor to be close to one

EXAMPLE A switch mode power supply with active power factor correction (PFC) circuit.

3.1.25
islanding
process whereby a power system is split into two or more islands

Note 1 to entry: Islanding is either a deliberate emergency measure, or the result of automatic protection or control action, or the result of human error.

[SOURCE: IEC 60050-603:1986, 603-04-31]

3.1.26
ITU regions
the three geographic regions defined within the Radio Regulations are as follows:

Region 1: Europe, Africa, the Middle East west of the Persian Gulf including Iraq, the former Soviet Union and Mongolia.

Region 2: The Americas, Greenland and some of the eastern Pacific Islands.

Region 3: Most of non-former-Soviet-Union Asia, east of and including Iran, and most of Oceania.

[SOURCE: ITU Radio Regulations, Section I, 5.2 to 5.4, 2012]

3.1.27
location (EMC)
position or site marked by distinguishing electromagnetic features

3.1.28
location class
set of locations having a common property related to the types and density of electrical and electronic equipment in use, including installation conditions and external influences

Note 1 to entry: See Annex A.

3.1.29
low voltage
LV
set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V AC

[SOURCE: IEC 60050-601:1985, 601-01-26]

3.1.30
magnetic field
constituent of an electromagnetic field which is characterized by the magnetic field strength H together with the magnetic flux density B

[SOURCE: IEC 60050-121:1998, 121-11-69]

3.1.31
maximum burst power
maximum instantaneous power achieved during a burst

3.1.32
medium voltage
MV
any set of voltage levels lying between low and high voltage

Note 1 to entry: The term medium voltage is commonly used for distribution systems with voltages above 1 kV and generally applied up to and including 52 kV (see IEC 62271-1).

[SOURCE: IEC 60050-601:1985, 601-01-28, modified – the note has been replaced by the current note.]

3.1.33
near field
region where the angular distribution of the electromagnetic field is dependent on the distance from the antenna

Note 1 to entry: When the antenna dimensions are smaller than the wavelength, then this region is defined as $d < \lambda/2\pi$, where d is the distance from the antenna and λ is the wavelength of the electromagnetic field.

3.1.34
port
particular interface of the specified equipment with the external electromagnetic environment

SEE: Figure 1.

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

3.1.35
power line telecommunications
PLT
use of existing in-building or network distribution power cabling as a metallic path for the distribution of data

Note 1 to entry: Power line telecommunications is also known as broadband power line (BPL) and power line communication (PLC).

3.1.36
power port
port at which a conductor or cable carrying the primary electrical power needed for the operation (functioning) of equipment or associated equipment is connected to the equipment

3.1.37
residential location
location which exists as an area of land designated for the construction of domestic dwellings, and is characterized by the fact that equipment is directly connected to a low-voltage public mains network or connected to a dedicated DC source which is intended to interface between the equipment and the low-voltage mains network

EXAMPLE Examples of residential locations are houses, apartments, and farm buildings used for living.

Note 1 to entry: The function of a domestic dwelling is to provide a place for one or more people to live. A dwelling can be a single, separate building (as in a detached house) or a separate section of a larger building (as in an apartment in an apartment block).

Note 2 to entry: The connection between location and electromagnetic environment is given in 3.1.15.

[SOURCE: IEC 61000-6-1:2016, 3.8]

3.1.38
signal port
port at which a conductor or cable intended to carry signals is connected to the equipment

EXAMPLE Analogue inputs, outputs and control lines, data busses, antennas, communication networks, etc.

3.1.39
short interruption
sudden reduction of the voltage on all phases at a particular point of an electric supply system below a specified interruption threshold followed by its restoration after a brief interval

Note 1 to entry: Short interruptions are typically associated with switchgear operations related to the occurrence and termination of short circuits on the system or on installations connected to it.

3.1.40
TN system
power system that has one point directly earthed at the source, the exposed conductive parts of the installation being connected to that point by protective conductors

Note 1 to entry: There are three types of TN systems: TN-S, TN-C and TN-C-S.

Note 2 to entry: A description of power systems is given in IEC 60364-1.

3.1.41
unbalance factor
in a three-phase system, the degree of unbalance expressed by the ratio (in per cent) between the r.m.s. values of the negative sequence (or the zero sequence) component and the positive sequence component of voltage or current

3.1.42
voltage change
variation of the r.m.s. or peak value between two consecutive levels sustained for definite but unspecified durations

Note 1 to entry: Whether the r.m.s. or peak value is chosen depends upon the application, and which is used should be specified.

[SOURCE: IEC 60050-161:1990, 161-08-01]

3.1.43
voltage dip
sudden reduction of the voltage at a particular point of an electricity supply system below a specified dip threshold followed by its recovery after a brief interval

Note 1 to entry: Typically, a dip is associated with the occurrence and termination of a short circuit or other extreme current increase on the system or installations connected to it.

Note 2 to entry: A voltage dip is a two-dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).

3.1.44
voltage fluctuation
series of changes of r.m.s. voltage evaluated as a single value for each successive half-period between zero-crossings of the source voltage

3.1.45
wave impedance
for a sinusoidal electromagnetic wave, using complex notation, the quantity representing the electric field at a point divided by the quantity representing the magnetic field at the same point

[SOURCE: IEC 60050-705:1995, 705-03-22]

3.1.46
Smart Grid
intelligent grid
electric power system that utilizes information exchange and control technologies, distributed computing and associated sensors and actuators, for purposes such as:

- to integrate the behaviour and actions of the network users and other stakeholders,
- to efficiently deliver sustainable, economic and secure electricity supplies via an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies

[SOURCE: IEC 60050-617:2011, 617-04-13, modified – the second bullet point has been updated.]

3.2 Abbreviated terms

AC alternating current

AIC active infeed converter

AM	amplitude modulation
AMN	artificial mains network
ASD	adjustable speed drive (also variable speed drive)
ATSC	advanced television systems committee
AV	average
AVE	audio-visual equipment
BPL	broadband over power line
CATV	communal antenna TV
CB	citizen band
CDMA	code division multiple access
CEPT	Conférence Européenne des administrations des Postes et des Télécommunications
	European Conference of Postal and Telecommunications Administrations
CISPR	Comité International Spécial des Perturbations Radioélectriques International Special Committee on Radio Interference
CMA	constant modulus algorithm
CT	cordless telephony
CT-2	cordless telephone, second generation
CW	continuous wave
DC	direct current
DCCS	digital cross connect system
DCS	digital cellular system
DECT	digital enhanced cordless telecommunications
DTX	discontinuous transmission
DVB-T	digital video broadcasting – terrestrial
DVD	digital versatile disc
DVR	digital video recorder
EAS	electronics article surveillance
EDM	electro-discharge machining
EIRP	effective isotropic radiated power
EM	electromagnetic
EMC	electromagnetic compatibility
EN	European Standard
ERC	European Radiocommunications Committee
ERMES	European radio messaging system
ERP	effective radiated power
ESD	electrostatic discharge
ETSI	European Telecommunications Standardisation Institute
EU	European Union
EUT	equipment under test
FCC	Federal Communications Commission
FDD	frequency division duplex
FDMA	frequency division multiple access
FHSS	frequency hopping spread spectrum

FM	frequency modulation
FOMA	freedom of mobile multimedia access
FRS	family radio service
FSK	frequency shift keying
GMSK	Gaussian minimum shift keying
GSM	global system for mobile communications
HIPERLAN	high performance radio local area network
HEMP	high-altitude EM pulse
HPEM	high power EM
HSPA	high speed packet access
HVAC	heating, ventilation and air conditioning
IEC	International Electrotechnical Commission
iDEN	integrated dispatch enhanced network
IEEE	Institute of Electrical and Electronics Engineers
IMT	international mobile telephone
ISDB-T	integrated services digital broadcasting – terrestrial
ISM	industrial, scientific and medical
ISO	International Organization for Standardization
ITE	information technology equipment
ITU	International Telecommunications Union
JP	Japan
LAN	local area network
LCL	longitudinal conversion loss
LF	low frequency
LPRS	low power radio service
LTE	long term evolution
LTE-A	long term evolution advanced
MRI	magnetic resonance imaging (also nuclear magnetic resonance)
MURS	multi-user radio service
N	neutral
NADC	North American digital cellular
OFDM	orthogonal frequency division multiplexing
PC	personal computer
PCC	point of common coupling
PDC	personal digital cellular
PDS	power drive system (also known as an adjustable speed drive or variable speed drive)
PE	indication for protective conductor
PEN	protective earth – neutral
PEP	peak envelope power
PHS	personal handy phone system
PK	peak
PLC	power line communications

PLT	power line telecommunications
PMR	public mobile radio
POCSAG	Post office code standard advisory group
PoE	ports of entry
POS	point of sale
PSD	power spectral density
PSTN	public switched telephone network
PV	photovoltaic
PVR	personal video recorder
PWM	pulse width modulated
RADAR	Radio Detection And Ranging
REIN	repetitive electrical impulse noise
RF	radio frequency
RFID	radio frequency identification
r.m.s.	root mean square
RTTT	road traffic and transport telematics
SHF	super high frequency
SHINE	single high intensity noise event
SRD	short range device
SNR	signal to noise ratio
SSB	single side band
TDD	time domain division
TDMA	time domain multiple access
TETRA	terrestrial trunked radio
THD	total harmonic distortion
TN-C	T means direct connection of one pole to earth, N means direct electrical connection of the equipment to the earthed point of the power distribution system (in AC systems, the earthed point of the power distribution system is normally the neutral point or, if a neutral point is not available, a phase conductor); C means the neutral and protective functions are combined in a single conductor.
TN-S	T means direct connection of one pole to earth, N means direct electrical connection of the equipment to the earthed point of the power distribution system (in AC systems, the earthed point of the power distribution system is normally the neutral point or, if a neutral point is not available, a phase conductor), S means the neutral and protective functions are separate conductors.
TV	television
UHF	ultra high frequency
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System
UPCS	Unlicensed Personal Communications Services
UPS	uninterruptable power system
US	United States of America

UTP	unscreened twisted pair
UV	ultra violet
UWB	ultra wide band
VCR	video cassette recorder
VDU	video display unit
VHF	very high frequency
WMTS	wireless medical telemetry service
WLAN	wireless local area network

4 User's guide for this document

4.1 Approach

Classification of the electromagnetic environment is based on the classification or a description of the electromagnetic phenomena prevailing at typical locations, not on existing test specifications. However, given a choice among equal possibilities, harmonization with existing test specifications (if appropriate) will simplify the situation and promote easier acceptance of the recommendations. The definition of electromagnetic environment in 3.1.15 refers to "electromagnetic phenomena". The term "disturbance degree" (3.1.9) is used in this document to quantify the phenomena contributing to the electromagnetic environment and it is independent of any consideration of test levels. The term "severity level" is not used in this document to describe the environment, as it is reserved for specifying immunity test levels in other IEC publications.

Thus, the concept and term of electromagnetic phenomenon is the starting point for defining the environment and selecting disturbance degrees in a classification document. Clauses 5, 6 and 7 of this document are the first step of the process. Three basic categories of phenomena have been identified: low-frequency phenomena, high-frequency phenomena and electrostatic discharge. In the first stage, attributes of the phenomena (amplitudes, waveforms, source impedance, frequency of occurrence, etc.) are defined generically, and the expected range of disturbance degrees established. Then, in the second stage, one single value from that range has been identified as most representative value for each phenomenon at a specific class of location and set forth as the compatibility level for that location class.

The process is illustrated in Figure 1, showing how two sets of tables are used: a set of input tables that are phenomena-oriented and establish a range of disturbance degrees for a given phenomenon, and a set of output tables that are location-oriented and propose a table for each class, with one value of compatibility level for each of the phenomena identified in the set of input tables.

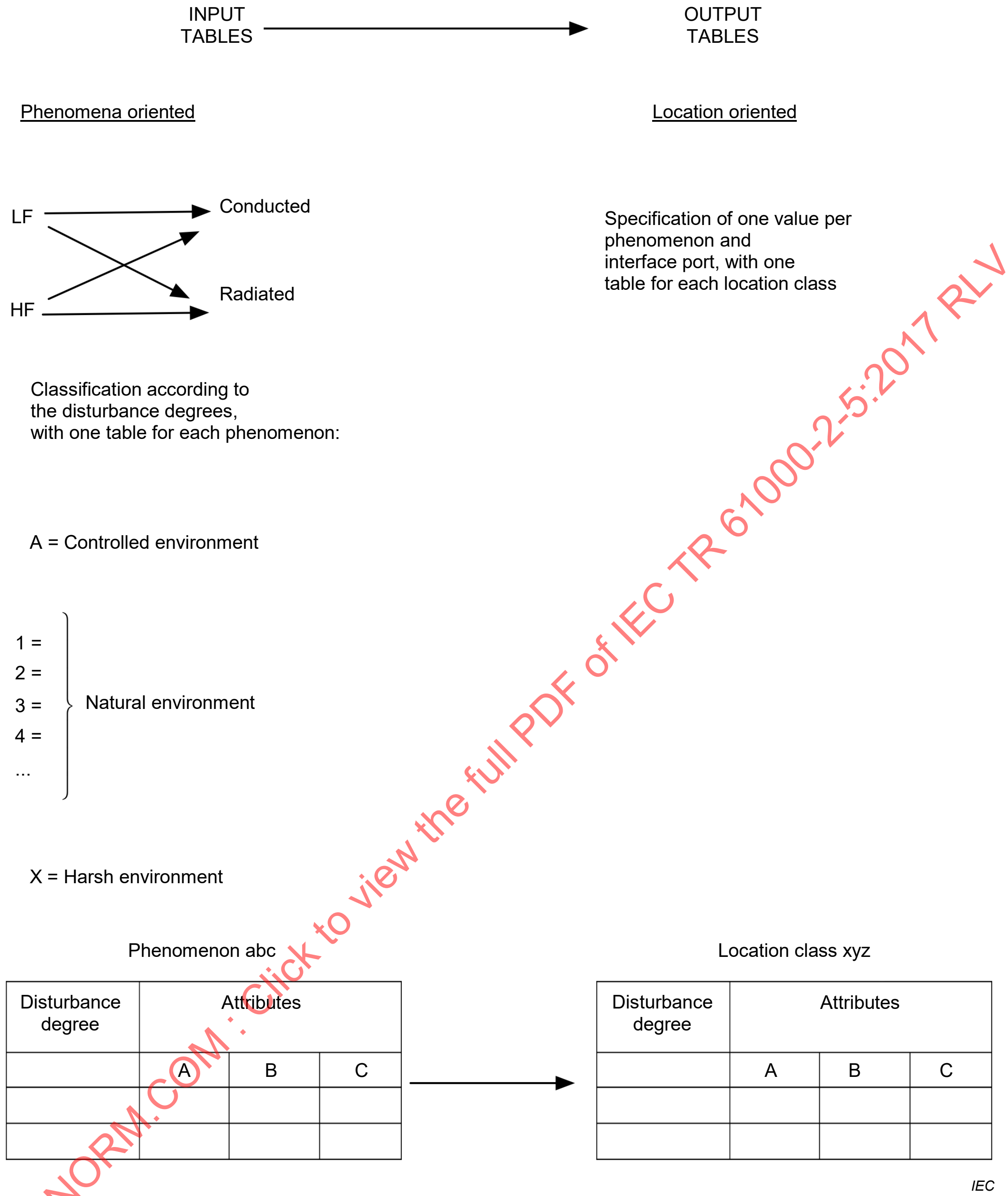


Figure 1 – Schematic of the two-step approach used for classification with phenomenon-oriented input tables and location-oriented output tables

Electromagnetic disturbances impinge on equipment by radiation or by conduction. A useful concept is to consider a set of ports, as shown in Figure 2, through which the disturbances enter (or exit) the equipment under consideration. The nature and degree of disturbing phenomena depends on the type of port, so that the tables in this document will take this into consideration. Electromagnetic radiated disturbances impinge on equipment from distant or close sources, hence the propagation and coupling can be governed by far-field or by near-field characteristics. Radiated disturbances that couple into the conductors connected to the equipment, but outside the equipment enclosure, become conducted disturbances. These are addressed under the various phenomena listed under conducted disturbances. The enclosure port shown in Figure 2 concerns only the radiated disturbances that enter the equipment through its envelope (either an actual barrier such as a shield, metallic cabinet, etc., or a physical barrier with no electromagnetic impact, such as a plastic housing).

The equipment shown in Figure 2 is a finished product with an intrinsic function for final use.

– The enclosure port is the physical boundary of the equipment, which electromagnetic fields may radiate through or impinge upon. The equipment case is normally considered the enclosure port.
– The signal port is the point where a cable carrying signals to or from the equipment or controlling the equipment can be connected. Examples are input/output (I/O) data/control lines, telecom lines, antenna cables, wired network lines, etc.
– The earth port is the point where a cable intended for connection to earth for functional or safety purposes can be connected.
– The power port is the point where a conductor or cable is connected to the equipment carrying the electrical power (AC or DC) needed for operation. The power port can be both input or output power port.

The significance of differentiating ports for conducted disturbances reflects the different types of phenomena that can occur in power systems versus communication systems, as well as the importance of earthing practices for each of the systems, as earth often serves as a reference for the equipment. For the purposes of this classification, the signal and control ports are considered similar and are therefore combined into the signal port. Users need to recognize that the values shown correspond to disturbances measured between the conductors of the specific systems, in what is described as a differential mode, a common mode or an asymmetrical mode.

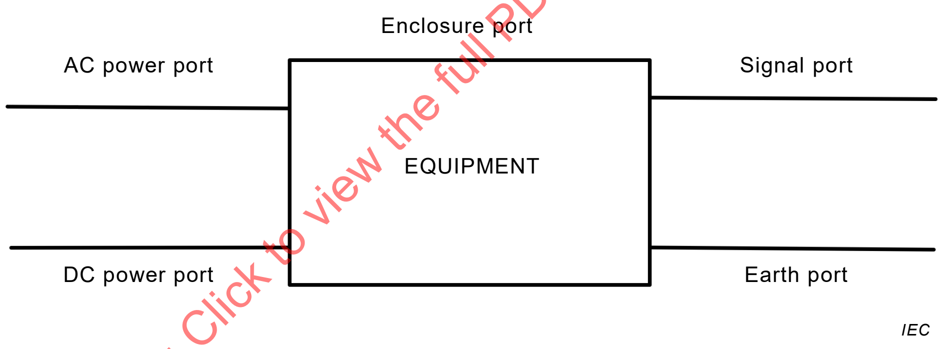


Figure 2 – Ports of entry (POEs) of electromagnetic disturbances into equipment

The final classification of environments into location classes and corresponding compatibility levels is discussed in Clause 8, with specific examples of location classes given in the tables of Annex A. In that respect three location classes have been identified in this document (see Figure 7). The attributes of these location classes are based on the significant electromagnetic characteristics of a location, rather than geographical or structural aspects. The location labels of the final classification imply specific definition of significant electromagnetic attributes. Classes of locations other than those listed in Annex A may be identified and added to the set as the need arises.

It should be noted that this classification is based on environment data collected up to 2015. The disturbance degrees shown in Annex A are offered as examples of compatibility levels for the guidance of product committees, not as immunity requirements. Those values are affected by uncertainties, and they may not cover extreme environments.

4.2 Rationale for classification system

The purpose of a classification system is to identify a limited set of parameters and associated values which may be chosen when identifying performance requirements. The purpose of such a system is primarily economic, in that it limits the number of variations in the number of types of equipment which a manufacturer may produce. It also identifies the need (if any) for appropriate interfaces.

The classification system proposed is rather exhaustive, and shows numerous electromagnetic phenomena. It does not necessarily mean that the immunity of a given item shall be tested against all these phenomena, but that a limited set of them may be chosen according to the environment of concern and inherent characteristics of the item.

4.3 Electromagnetic environment phenomena

The electromagnetic environment in which electrical and electronic items are expected to operate without interference is very complex. For the purpose of this classification, three categories of electromagnetic environment phenomena have been defined to describe all disturbances:

– electrostatic discharge (ESD) phenomena (conducted and radiated);
– low-frequency phenomena (conducted and radiated, from any source except ESD);
– high-frequency phenomena (conducted and radiated, from any source except ESD).

This distinction is necessary in order to recognize that electromagnetic disturbances occur in a particular medium. Formally, when dealing with the electromagnetic environment, the wavelength λ of the considered disturbance is the gauge for "long or large" and for "short or small". An item is small or a line is short if the wavelength is much greater than its dimensions. Consequently, in that situation the frequency is low, as the frequency is inversely proportional to wavelength. An item is large or a line is long if the wavelength is much smaller than its dimensions. However, in the context of the present document and in accordance with the IEC EMC approach, the term low frequency applies to frequencies up to and including 9 kHz; the term high frequency applies to frequencies above 9 kHz.

Electromagnetic radiation in different locations may be a result of intentional or unintentional radiators and may include electromagnetic fields on frequencies from 0 Hz (static fields) to 400 GHz. Electromagnetic fields can be radiated from distant or close sources, hence the propagation and coupling can be governed by far-field or by near-field characteristics. The resulting field strength at a location is typically controlled by the radiated power, the distance from the radiator and coupling effectiveness. The frequency is also an important factor in order to describe electromagnetic fields at a location.

Radiated disturbances occur in the medium surrounding the equipment, while conducted disturbances occur in various metallic media. The concept of ports as shown in Figure 2, through which disturbances have an impact on the item, allows a distinction among the following various media:

1) enclosure;
2) AC power mains;
3) DC power mains;
4) signal lines;
5) interface between items and earth or reference.

The source, the coupling and the propagation characteristics depend on the type of medium. The final tables of Annex A show the compatibility levels for various location classes, and are structured along this concept of corresponding ports.

4.4 Relationship of disturbance levels to CISPR limits

In general compatibility levels are used as reference for coordination in the setting of emission limits and immunity levels (see also IEC TR 61000-1-1). The disturbance levels given in this document should be used to determine the compatibility levels.

Emissions from equipment (or from a system made of items of equipment) should be set in such a way that together with appropriate immunity levels of other items of equipment electromagnetic compatibility is achieved. The easiest approach would be to set the emission limits lower than the immunity levels, placing a margin between limits and levels which takes into account, for example, tolerances in the hardware properties of the items of equipment, potential coupling mechanisms between items of equipment and statistical considerations.

Hence, setting emission limits in this way predominantly aims at the achievement of electromagnetic compatibility. Such types of emission limits are not related to CISPR emission limits as for the specification of CISPR limits a different approach is applied.

CISPR limits are developed for protection of radio communications. They take into account aspects such as field strength signals needed for radio reception or typical protection distances between radio receivers and potential interference sources (typically 10 m or 30 m). They do not take into account the situation in very close proximity of disturbance sources (as this is not a typical situation for reliable radio reception) or immunity issues as the CISPR emission limits are normally far below (several magnitudes) typical immunity levels. In this respect, emission limits derived from the disturbance levels of this document and CISPR limits are not always correlated with each other. Consequently, the disturbance levels of this document are in most cases not appropriate to derive CISPR limits.

NOTE More detailed information about determining CISPR emission limits are given in CISPR TR 16-4-4.

4.5 Simplification of the electromagnetic environment database

It is neither possible nor absolutely necessary to describe completely an electromagnetic environment. Consequently, any description is limited to certain properties of this environment. The first step of a description should be the selection of appropriate electromagnetic properties corresponding to the various phenomena that can create electromagnetic disturbances. Table 1 lists these phenomena. In this document, the boundary between low frequency and high frequency is generally understood as being 9 kHz; however, when addressing a type of disturbance prevailing in one frequency range with a small overlap into the other range, the boundary might be slightly shifted to keep the phenomenon within one descriptive range.

An appropriate selection is only valid if its purpose is also specified. Considering the many possible coupling mechanisms between an item and its electromagnetic environment, it becomes apparent that, in order to accurately assess the necessary level of immunity for any item, more information than is available about the environment would be needed. Accuracy of electromagnetic environment descriptions is necessarily limited, as follows:

– some aspects of the environment are disregarded because the information is not available;
– some aspects of the environment are disregarded because a classification system taking them into account would become too complex;
– a statistical approach may be necessary, in order to consider only those events for which the occurrence is likely.

The first two limitations are embedded in the selection of the disturbance types, while the statistical aspect appears in the definition of environment classes and the selection of a single value for compatibility levels, rather than a range of values.

Available databases at the time of elaboration of this document indicate the wide variety of conducted and radiated disturbances that can be expected to occur in the diverse environments encountered in the use of equipment. Evaluation by laboratory tests of the ability of equipment to withstand these environments, or of the effectiveness of mitigation methods, can be facilitated by a synthesis of the database. This synthesis leads to selecting a few representative disturbance phenomena that will make tests uniform, meaningful and replicable.

Table 1 – Principal phenomena causing electromagnetic disturbances

Phenomena		Table	Subclause
LF-conducted			
Power supply networks	Harmonics/inter-harmonics	2	5.1.1
	Voltage fluctuations	3	5.1.2.1 a)
	Voltage dips	None	5.1.2.1 b)
	Voltage interruptions	None	5.1.2.1 c)
	Voltage unbalance	4	5.1.2.1 d)
	Voltage frequency variations	5	5.1.2.2
Power supply networks	Common mode voltages	6	5.1.3
	Signalling voltage 0,1 kHz to 3 kHz	7	5.1.4
	Induced LF	8	5.1.6
	DC in AC networks	None	5.1.7
Signal and control cables	Induced LF (normal conditions)	8	5.1.6
	Induced LF (fault conditions)	8	5.1.6
LF magnetic field	DC	9	5.2.1
	Railway	9	5.2.1
	Power system	9	5.2.1
	Power system harmonics (n = harmonics)	9	5.2.1
	not power system related	9	5.2.1
LF electric field	DC lines	10	5.2.2
	Railway (16,7 Hz)	10	5.2.2
	Power system (50 Hz/ 60 Hz)	10	5.2.2
HF phenomena			
Signalling voltage/PLT	3 kHz to 95 kHz	7	5.1.4
	95 kHz to 148,5 kHz	7	5.1.4
	148,5 kHz to 500 kHz	7	5.1.4
Direct-conducted CW/PLT (intentional)	1,606 5 MHz to 87,5 MHz	None	6.1.2
Direct-conducted CW (unintentional)	9 kHz to 150 kHz	11	6.1.2.4
HF-conducted induced CW	10 kHz to 150 kHz	12	6.1.3
	0,15 kHz to 150 MHz	12	6.1.3
Unidirectional transients	Nanoseconds	13	6.1.4
	Microseconds, close	13	6.1.4
	Microseconds, distant	13	6.1.4
	Milliseconds	13	6.1.4
HF-conducted oscillatory transients	High frequency	14	6.1.4
	Medium frequency	14	6.1.4
	Low frequency	14	6.1.4
HF radiated			

Phenomena		Table	Subclause
Radiated CW	ISM Group 2	16	6.2.2
Radiated modulated	Mobile units GSM DCS1800 DECT	21, 22	6.2.3.2
	Base stations	23, 24	6.2.3.2
	Medical and biological telemetry items	25	6.2.3.2
	Digital television broadcast	26, 27, 28	6.2.3.2
	Unlicensed radio services	29, 30	6.2.3.2
	Paging services (base station)	32	6.2.3.2
	RFID + railway transponder	39, 40	6.2.3.3
	Other RF items	19, 20, 33, 34, 35, 36, 37, 38	6.2.3.2
	Amateur radio stations	17 31	6.2.3.1 6.2.3.2
	CB	18	6.2.3.1
Radiated pulsed	Radiated transients	41	6.2.4
	RADAR	42	6.2.4
ESD	Slow Fast	43 / 44 43 / 44	7.2 / 7.3 7.2 / 7.3
High altitude electromagnetic pulse (HEMP)	Not considered in this document; for further information see IEC 61000-2-9		
High power electromagnetic pulse (HPEM)	Not considered in this document; for further information see IEC 61000-2-13		

To assist equipment designers and users in making appropriate choices in defining immunity test levels, the classification shows, for each phenomenon, only one compatibility level per class of location. The characterization of each phenomenon is presented in tabular form, from which a selection can be made. This approach gives a common base of reference for specifying immunity requirements for an item of equipment expected to be installed at various locations, and yet provides the appropriate degree of compromise between a conservative overdesign and a cost-conscious reduction of margins. The specification of these requirements for specific equipment remains the field of product standards and, therefore, cannot be addressed in the present document.

For a given equipment, the surrounding environment in which it is required to operate results from the presence and nature of disturbance sources, as well as from the installation conditions adopted. Typical installation practices take into consideration the mitigation which can be obtained by separation, shielding and suppression. Therefore, it is important to take into consideration the effect of these practices when suggesting disturbance degrees in specific locations where various installation practices are generally applied. This document assigns a representative degree for the various types of installations likely to be found at those locations.

The listing of disturbance degrees includes an "A" degree, for an environment where some mitigation or control might be necessary to satisfy specific requirements, and an "X" degree recognizing that in some situations exceptional conditions could prevail that need specific recognition. The "A" degree corresponds to a situation where the environment is somewhat controlled by the nature of the building, or installation practices inherent to a particular location class. The "X" degree corresponds to a degree of disturbance higher than is generally encountered.

As with any classification scheme, its value lies in its generality. This classification recognizes that there could be exceptional requirements associated with any specified location. The consequences of such an occurrence shall be taken into account in designing equipment for operation in a particular classification category. For example, a particular type of switching transient can occur infrequently in some location classes. Whether the equipment should be designed to be "immune" to this particular disturbance depends upon whether its effects are temporary (for instance, a reduction of reception quality that might be acceptable although undesirable), or permanent and unacceptable (equipment damage or malfunction with unacceptable consequences).

If no special performance requirement is expected at a given location, which is the general case, the procedure is reduced to:

- selecting the appropriate location class from those defined in Clause 8 and Annex A;
- selecting the required immunity in accordance with the principles stated in Clause 9.

The purpose of this document is not to specify immunity, but to allow product committees to make a selection on a rational and informed basis, without specifying equipment immunity. Data shown in the Table 2 to Table 14 and Table 16 to Table 44 refer to well-known electromagnetic environment conditions, such as low-frequency phenomena or, in other cases, only proposed as representative levels for classification.

5 Low-frequency electromagnetic phenomena

5.1 Conducted low-frequency phenomena

5.1.1 Harmonics of the fundamental power frequency

Harmonic voltages of the fundamental power frequency exist on power supply networks. The source is harmonic currents of the fundamental power frequency that are injected into the power supply network by attached non-linear loads, where they are converted into voltages by the network impedance.

The number of non-linear loads that are utilised in residential, commercial and industrial locations has increased significantly in recent years. There are two types of non-linear loads:

– The very large number of small capacity loads (i.e. each consuming less than 1 kW), mostly single-phase loads, that are found in the low-voltage power distribution network. Such loads typically have rectifier input and include items such as household appliances, AVE, ITE, etc.
– The small number of large capacity loads (i.e. each consuming more than 1 kW) that may be found in low-voltage, medium-voltage and high-voltage power distribution networks. Such loads include industrial power drive systems and other manufacturing devices.

For low-voltage public supply networks, the main sources of harmonic voltages are the very large number of small capacity loads. IEC 61000-1-4 reviews the sources and effects of the emissions of power frequency conducted harmonic currents in the low-voltage networks.

For low-voltage, medium-voltage and high-voltage industrial power supply networks, the main sources of harmonic voltages are the small number of large capacity loads.

Harmonics from residential, commercial and industrial areas aggregate to disturb the voltage of the supply network. Table 2 shows:

– the disturbance levels for the individual voltage harmonic components;
– the THD:

$$THD = \sqrt{\sum_{n=2}^{40}\left(\frac{U_n}{U_1}\right)^2} \qquad (1)$$

where

U_n is the amplitude of the n^{th} harmonic of the fundamental power frequency;

U_1 is the amplitude of the fundamental power frequency.

NOTE 1 The definition of the THD recognises the fact that not all harmonic components will reach their peak amplitude simultaneously.

NOTE 2 Harmonics up to and including the 40^{th} harmonic are considered, in conformity with IEC 61000-3-2.

Table 2 – Disturbance degrees and levels for harmonic voltages in power supply networks (in percentage to fundamental voltage, U_n/U_1)

Harmonic order	THD	Odd (non-multiple of 3)								Odd and multiple of 3					Even			
		5	7	11	13	17	19	23-25	>25	3	9	15	21	>21	2	4	6-10	>10
Basic document **Disturbance degree**	IEC 61000-2-2, IEC 61000-2-4 and IEC 61000-2-12																	
A (Controlled)	Case-by-case according to the equipment requirements																	
1	5	3	3	3	3	2	a	a	a	3	1,5	0,3	0,2	0,2	2	1	0,5	c
2	8	6	5	3,5	3	2	a	a	a	5	1,5	0,4	0,2	0,2	2	1	0,5	c
3	10	8	7	5	4,5	4	b	b	b	6	2,5	2	1,75	1	3	1,5	1	1
X (harsh)	Case-by-case according to the situation																	

NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4.

NOTE 2 Class 1 applies to protected supply networks and has compatibility levels lower than those of public supply networks. It relates to the use of equipment that is very sensitive to disturbances in the power supply, for instance the instrumentation of technological laboratories, some automation and protection equipment, some computers, etc.

NOTE 3 Class 2 applies to low-voltage public supply networks (see IEC 61000-2-2). It can also apply to commercial and light industrial environments (small- and medium-size industrial plants, commercial buildings).

NOTE 4 Class 3 applies to industrial environments. It has higher compatibility levels than those of Class 2 for some disturbance phenomena. For instance, this class would be considered when any of the following conditions are met:

– a major part of the load is fed through power converters;

– welding machines are present;

– large motors are frequently started;

– loads vary rapidly.

NOTE 5 Class X applies to an arbitrarily defined environment, for example, strongly disturbed industrial power supply networks (steel plants, power stations, etc.).

The above levels correspond to those values that are not exceeded by 95 % of the 10 min mean r.m.s. values during each period of one week under normal operating conditions (taken from EN 50160).

a = 2,27 × (17/n) – 0,27 (where n is the order of the harmonic component)

b = 4,5 × (17/n) – 0,5 (where n is the order of the harmonic component)

c = 0,25 × (10/n) + 0,25 (where n is the order of the harmonic component)

5.1.2 Power supply network voltage amplitude and frequency changes

5.1.2.1 Amplitude change

The voltage amplitude of the 50/60 Hz power network can be subject to various disturbances.

a) Continuous or randomly repeated and relatively rapid fluctuations within the normal operating range occur at a frequency ranging from 25 times per second to one time per minute. The most disturbing effect of such fluctuations is a flickering of lighting levels (mainly low-voltage incandescent lamps), causing physiological discomfort. Sources are generally industrial loads such as arc furnaces (HV network), welding machines (LV network) and switching of large loads or capacitor banks. Table 3 lists disturbance levels for voltage fluctuations within normal operating range.

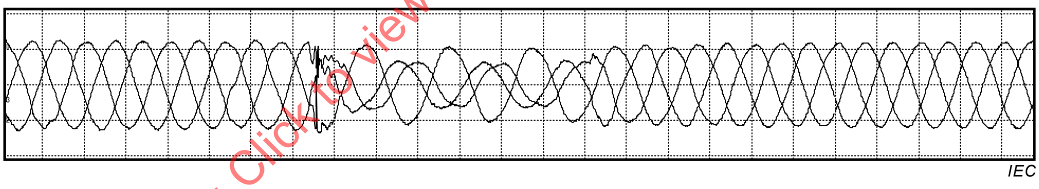
Table 3 – Disturbance degrees and levels for voltage changes within normal operating range (in percentage of nominal voltage, $\Delta U/U_n$)

Disturbance degrees	Basic standard
	IEC 61000-2-4
	Disturbance levels
A (controlled)	Case-by-case according to the equipment requirements
1	±8 %
2	±10 %
3	−15 % to +10 %
X (harsh)	Case-by-case according to the situation
NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4. NOTE 2 A range of −15 % to +10 % can occur for a duration shorter than 60 s. For longer duration, a range of −10 % to +10 % applies.	

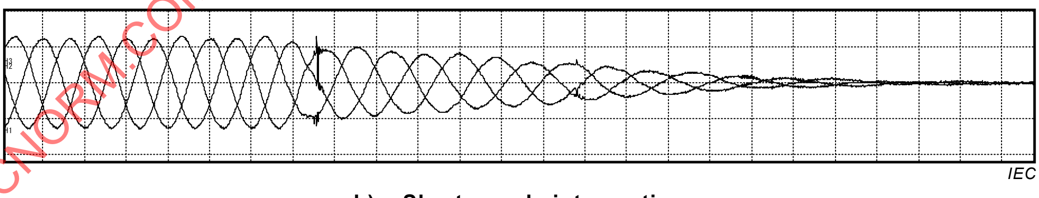
b) Voltage dips last in most cases for less than 1 s. In areas supplied by overhead lines, the number of voltage dips can reach several hundreds per year, depending on the number of lightning strokes and other meteorological conditions in the area. In areas supplied by underground power cables an individual user of electricity connected at LV may be subject to voltage dips occurring at a rate that extends from around ten per year to about a hundred per year, depending on local conditions.

c) Short supply interruptions with durations ranging up to 180 s also occur. Most of them are restored within 60 s. Interruptions lasting more than 180 s are no longer considered an EMC issue, but a blackout.

d) Voltage unbalance can be caused by asymmetrical loads or large single-phase loads such as traction systems or single-phase furnaces. Table 4 shows the disturbance degrees.



a) – Voltage dip



b) – Short supply interruption

Figure 3 – Typical voltage waveforms for dip and interruption (10 ms/horizontal division)

NOTE 1 Voltage dips and short interruptions have various origins:

– short circuits in LV networks cleared by fuse operation (a few milliseconds);

– faults on MV and HV overhead lines or other equipment, followed or not followed by automatic reclosure (almost 70 ms to 1 000 ms);

– switching of large loads, especially motors and capacitor banks.

Examples of voltage waveforms for voltage dip and short supply interruption are shown in Figure 3.

NOTE 2 The disturbance degrees and compatibility levels for these phenomena, i.e. voltage dips and short supply interruptions, are not yet available. Further information and suitable immunity levels on these phenomena are given in IEC 61000-2-2, IEC 61000-2-4, IEC TR 61000-2-8, IEC 61000-4-11 and IEC 61000-4-34.

Table 4 – Disturbance degrees and levels for voltage unbalance (in percentage of U_{neg}/U_{pos})

Disturbance degrees	Basic standard
	IEC 61000-2-2, IEC 61000-2-4 and IEC 61000-2-12
	Disturbance levels
A (controlled)	Case-by-case according to the equipment requirements
1	2 %
2	2 %
3	3 %
X (harsh)	Case-by-case according to the situation
NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4. NOTE 2 Levels are indicated for the ratio of the negative phase sequence component to the positive one.	

5.1.2.2 Frequency change

The fundamental frequency of a power supply network is generally very stable, varying by no more than 0,2 %. However, during network disturbances, the fundamental frequency of the power network can vary by up to 4 % (see Table 5).

Table 5 – Disturbance degrees and levels for power frequency variation

Disturbance degrees	Basic standard
	IEC 61000-2-2, IEC 61000-2-4 and IEC 61000-2-12
	Disturbance levels
A (controlled)	Case-by-case according to the equipment requirements
1	±1 Hz
2	±1 Hz
3	±1 Hz
X (harsh)	Case-by-case according to the situation
NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4. NOTE 2 For isolated power networks, ±2 Hz applies.	

5.1.3 Power supply network common mode voltages

In power supply networks, both phase voltages and phase-to-phase voltages should be identified. Phase voltages correspond to the phase conductor voltages against the ground concerned. Phase-to-phase voltages can be regarded as normal mode (or differential mode) voltages, while the common mode voltage is given by the average of the phase voltages. For polyphase systems the common mode voltage equals the neutral line voltage. Since the neutral line is usually grounded, relative current flows through the neutral conductor when the common mode voltage occurs.

A common mode voltage should be stationary in power supply networks. If high-frequency components are contained in it, insulation breakdown, increase of grounding current or noisy electromagnetic radiation may occur. An electric shock could also occur in the worst case.

Semiconductor power converters are widely adopted in industrial machines and distributed generators, such as PDS, PV generation, etc. In many cases, these devices are connected to the power supply network directly, without transformers. This arrangement may change the common mode voltage of the input/output lines rapidly with the switching frequency. In the case of PWM converters, the frequency of the common mode voltage change can range from several hundred Hertz to over 100 kHz.

Figure 4 shows a typical configuration of the semiconductor converter in a PDS: a 3-phase AC network voltage is rectified to DC voltage by a diode-rectifier. For the purpose of simplifying the explanation, the neutral point of the AC network is assumed to be grounded. The DC voltage is further converted to a 3-phase AC voltage with adjustable frequency and amplitude by a PWM inverter. The output voltage feeds an induction or synchronous motor.

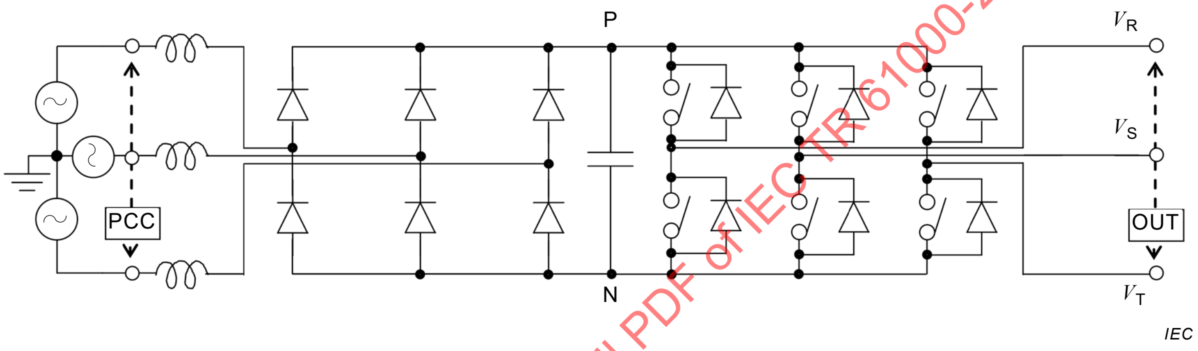
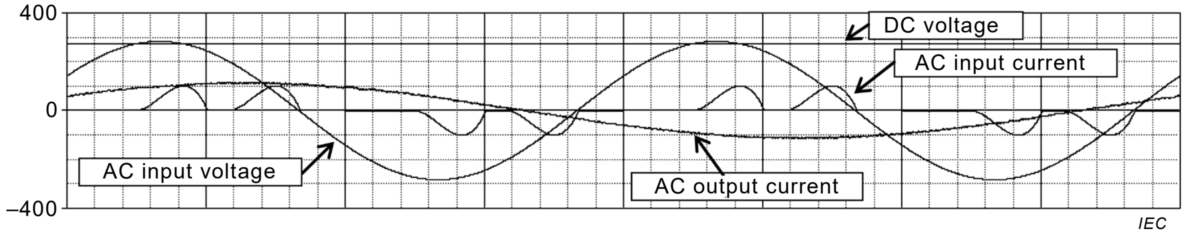


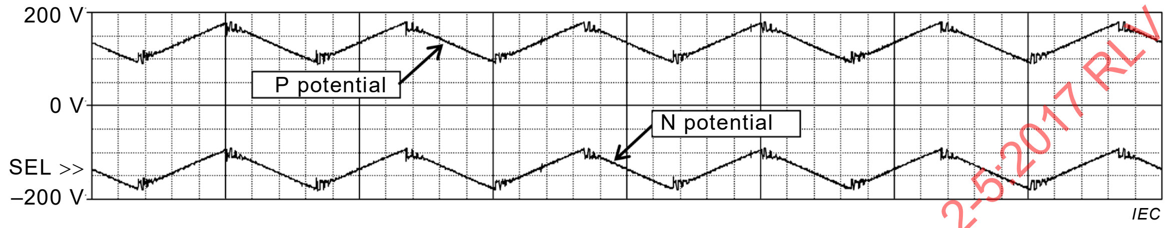
Figure 4 – Typical configuration of the converter in a PDS

Figure 5 depicts an example of the voltage and current waveforms at each position in a PDS. The AC network frequency is 50 Hz. The PDS output frequency is 25 Hz. A representative AC input phase-to-phase voltage, a representative AC input phase current, the DC voltage and a representative AC output phase current are shown in of Figure 5a). The AC input phase current includes large harmonic components, whereas the AC output current is controlled to be almost sinusoidal. Figure 5b) indicates both the DC positive pole (P) voltage potential from the ground and that of the negative pole (N). The DC line potential from the ground fluctuates at 150 Hz (50 × 3). The DC differential voltage fluctuates at 300 Hz (50 × 6), though this fluctuation is very small. Figure 5c) displays the common mode (neutral) voltage of the converter output, which contains multiples of the PWM carrier frequency (5 kHz) components. The envelope of the common mode voltage follows the DC P and N potential voltages. It is the significant feature of PDS that the output common mode voltage is pulsating at the PWM carrier frequency although the output current gets almost sinusoidal.

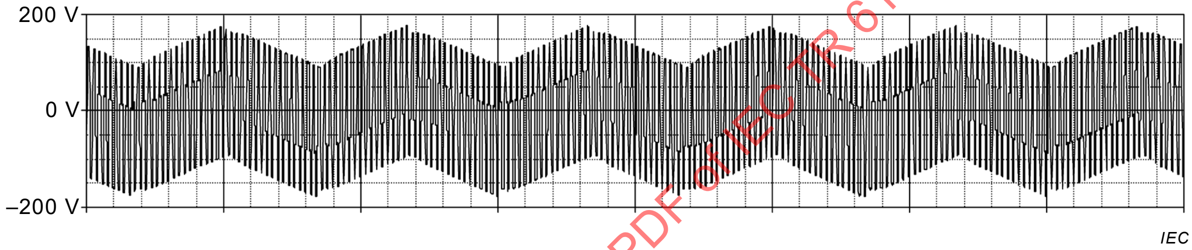
One example of a measured PDS common mode voltage is introduced in Figure 6. The Figure was taken for between 150 kHz and 30 MHz through an AMN. The motor capacity was 3,7 kW and the switching frequency of the PDS was 14,5 kHz. Since a peak measuring receiver was used instead of a quasi-peak measuring receiver, the detected value would be several dB higher. It is found that about 100 dB(μV) conducted common mode disturbance voltage is generated.



a) – Waveforms of input and output currents, and link voltage

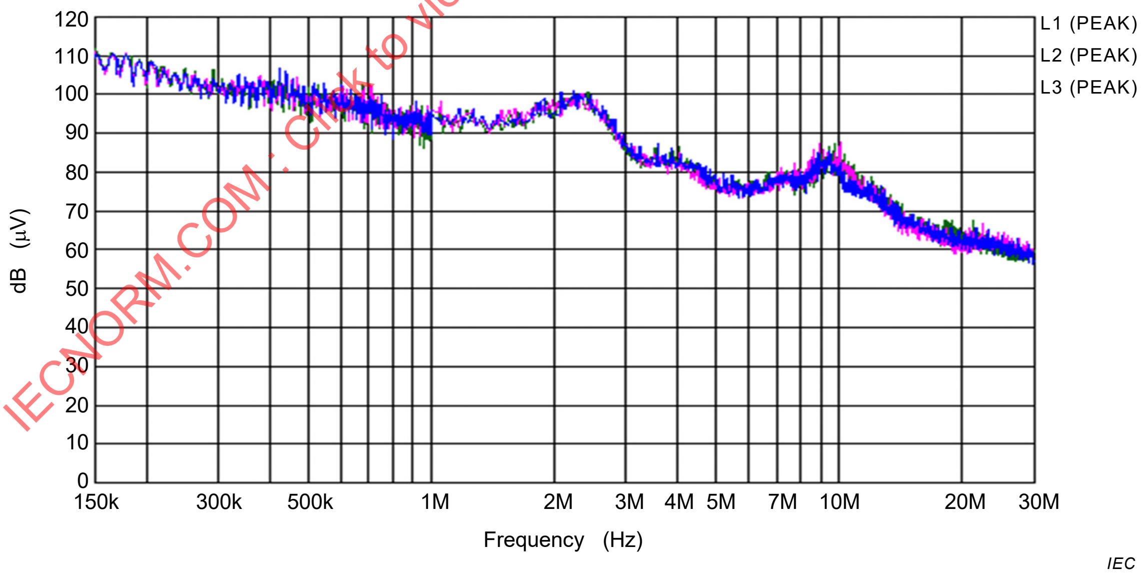


b) – DC link potential fluctuation



c) – Common mode voltage of the converter output

Figure 5 – Voltage and current waveforms of each PDS portion (1 ms/horizontal division)



NOTE The common mode voltage produced by a PDS causes various interferences:

1) Rise of bearing current resulting in lifetime reduction.

2) Surge voltage resulting in insulation deterioration of motor windings.

3) Generation of stationary grounding current.

4) Induced radio interference.

Figure 6 – Measured common mode voltage at the input terminal of a converter

Disturbance degrees and levels for common mode voltages are given in Table 6.

Table 6 – Disturbance degrees and levels for common mode voltages

Disturbance degrees	Basic standard
	IEC 61000-4-16
	Disturbance levels
1	1 V
2	3 V
3	10 V
4	30 V
X (harsh)	Case-by case according to the situation

NOTE 1 A more detailed description of the environments in terms of installation conditions or equipment under operation is given in IEC 61000-4-16:2015, Annex B.

NOTE 2 Values in $V_{r.m.s.}$

5.1.4 Signalling voltages in power supply networks

Power supply networks are designed for the transmission of energy, but they can also be used for the transmission of information by mains signalling systems. The relevant standardization documents consider three types of systems:

- ripple control systems that are used by electrical utilities in public supply networks, in the range of 100 Hz to 3 kHz, generally below 500 Hz, with signals up to 5 % of U_n under normal circumstances and up to 9 % of U_n in cases of resonance. These systems are used in some countries in Europe and elsewhere;
- power-line carrier systems used by electrical utilities in public supply networks, in the range 3 kHz to 95 kHz, with allowed signal levels up to 5 % of U_n. These signals are strongly attenuated in the network (> 40 dB). These systems are used mainly in Europe, in the US and are developing elsewhere;
- signalling systems for end-user premises (residential or industrial) in the range of 95 kHz to 148,5 kHz in Europe (ITU region 1), with allowed signal levels up to 0,6 % U_n or 5 % U_n, respectively. In the US and Japan the upper frequency is 500 kHz, with allowed signal levels between 2 mV and 0,6 mV.

Disturbance degrees and levels for signalling voltages in power systems are given in Table 7.

Table 7 – Disturbance degrees and levels for signalling voltages in low and medium-voltage systems (in per cent of nominal voltage U_n)

Disturbance degrees	**Frequency range** in kHz			
	0,1 to 3	3 to 95	95 to 148,5	148,5 to 500
	Disturbance levels			
A (controlled) [a]	Case-by-case according to the equipment requirements			
1 [b]	0,1 kHz to 0,5 kHz: 9 % U_n [d] 0,5 kHz to 0,95 kHz: 9 % U_n to 5 % U_n [d] 0,95 kHz to 3 kHz: 5 % U_n [d]	3 kHz to 9,5 kHz: 5 % U_n [d] 9,5 kHz to 95 kHz: 5 % U_n to 1,3 % U_n [d]	General: 0,6 % U_n Industrial areas: 5 % U_n	2 to 0,6 (mV, not %)
X (harsh) [c]	Case-by-case according to the situation.			

NOTE 1 Degree A: residual signals might exist, coupled from adjacent systems where intentional signals might be present. For this degree, in contrast with other tables, degree A is not a controlled environment. Furthermore, some types of installations might offer some degree of protection against this disturbance phenomenon. In case of disturbing over-spill from adjacent networks, it might be necessary to install blocking or absorbing circuits.

NOTE 2 Degree 1: for the range 0,1 kHz to 3 kHz, the values correspond to normal injection levels in actual installations. For the other ranges, the values indicate the maximum allowed injection level measured on a reference impedance. These values are only applied in ITU region 1, and other values might be used in ITU region 2 or 3.

NOTE 3 Degree X: normally the signals are more or less attenuated in the network. However, in certain cases of resonance the signals can be enhanced.

[a] Network without signalling.

[b] Emission level, near to the transmitter.

[c] Special cases (resonances).

[d] EN 50160:2010 (Figure 1 and Figure 2) gives information on possible levels of signaling voltages which may be present in public power supply networks. The values are valid for low-voltage and medium-voltage power supply networks.

5.1.5 Islanding supply networks

The term islanding describes the process whereby a power system is split into two or more islands. Islanding mainly occurs when either a deliberate emergency measure or an automatic protection/control action is taken. If the scale of an islanding network is relatively small, its power frequency fluctuation and voltage fluctuation can be larger than usual.

To protect installations like hospitals, server farms, shopping centres and warehouses during ‘black outs’ or ‘brown outs’, most of these installations have an independent backup system for their power supply. This is done by either a backup generator or a UPS. When the backup system is in operation, the fluctuation in both the power frequency and the voltage amplitude can be larger than the normal conditions specified in 5.1.2.

Islanding is not limited to the situations mentioned above. For some environments the situation of a relatively small power supply network can be the normal situation. Examples of such environments include:

– a small island, town or house that is physically isolated from a public distribution network and hence has a separate, independent power supply network that is driven by diesel generator, photovoltaic power system or other power source;

– a vessel (ship or aircraft) or off-shore installation.

In these situations the normal power quality conditions may not exist. It is recommended for small power networks that a case-by-case assessment be performed to determine the various aspects of power quality.

5.1.6 Induced low-frequency voltages

Low-frequency currents in cables might (according to actual currents, physical layout, cable type and other parameters) induce low-frequency common mode voltages into adjacent cables. The coupling impedance varies according to the proximity of the cables and the effective parallel length.

Table 8 describes induced common mode voltages. Differential mode voltages may also occur and are strongly dependent on the type of cable, termination and earthing arrangement.

Table 8 – Disturbance degrees and levels for low-frequency, common mode induced voltages in signal and control cables

Disturbance degrees	Phenomena (sources) and basic standard				
	Power distribution and mains cables carrying network frequency and harmonics under normal operating conditions IEC 61000-4-16				Fault condition in power system [a] IEC 61000-4-16
	Disturbance levels				
	15 Hz to 150 Hz [c]	150 Hz to 1,5 kHz	1,5 kHz to 15 kHz [d]	15 kHz to 150 kHz	50 Hz to 1 kHz
A (controlled)	Case-by-case according to the equipment requirements				
1	1 to 0,1	0,1	0,1 to 1	1	100
2	3 to 0,3	0,3	0,3 to 3	3	300
3	10 to 1	1	1 to 10	10	1 000
4	30 to 3	3	3 to 30	30	3 000 [b]
X (harsh)	Case-by-case according to the situation				

NOTE Values in $V_{r.m.s.}$

[a] Values may be limited by ITU-T or other mandated mitigation methods.

[b] May be limited by sparkover of clearances. On insulated ground circuits, higher voltages might occur.

[c] The disturbance levels decrease by 20 dB/decade.

[d] The disturbance levels increase by 20 dB/decade.

5.1.7 DC voltage in AC networks

DC voltage in AC networks is caused primarily by geomagnetic storms that may induce high levels of quasi–DC currents in the high-voltage network. DC currents as high as hundreds of amperes have been measured in high-voltage networks, thereby reducing voltages of up to 10 % of rated voltage for times of hundreds of seconds. In addition, harmonics are created in transformers, which propagate throughout the power network. As these events are rare (once per year) and regional (northern and southern latitudes), it is recommended that these events be considered as a very low probability at a particular location. It is noted that under severe circumstances, a voltage collapse of the entire power network can result.

It is difficult to assign a precise disturbance level to this rare phenomenon, however, class 3 harmonic levels in Table 2 and class 3 voltage fluctuations in Table 3 could be considered as appropriate for all locations connected to the public power supply network.

5.2 Radiated low-frequency phenomena

5.2.1 Magnetic fields

Magnetic fields in the power frequency range are produced by several types of sources:

- nearby power cables and lines, in particular overhead power lines
- stray fields from transformers
- bus bar systems
- switchgear installations
- power system equipment, such as power drive systems, rectifiers, generators, etc.

In the case of power cables, magnetic fields might occur also due to common mode currents, depending on the type of the power supply system (e.g. in the case of TN-C systems, see 8.6).

The frequencies or frequency ranges to be considered depend on the type of sources existing at the location under consideration and comprise:

- DC
- frequencies of railway traction system (e.g. DC, 16 2/3 Hz, 50 Hz, 60 Hz, ...)
- fundamental frequency of power supply systems
- harmonics occurring in a power system
- frequencies not related to power systems

Significant magnetic fields at harmonic frequencies appear only in special circumstances, for example in the presence of power electronic systems.

Case-by-case consideration is required in presence of particular nearby high power equipment (electrolysis, generators, etc.), within high power installations (switchyards, power stations, etc.) or for particular types of equipment (magnetic resonance equipment, induction heating, etc.). Table 9 quantifies the magnetic fields from various low-frequency sources.

Table 9 – Disturbance degrees and levels for low-frequency magnetic fields at various frequencies

Disturbance degree	**Phenomena (sources)**				
	DC [a]	Railway frequency 16,7 [b, f]	Power system frequency 50/60 Hz [c]	Harmonics of power system 0,1 kHz to 3 kHz [d]	Not related to power systems [e]
	Disturbance levels				
A (controlled)	Case-by-case according to the equipment requirements				
1	3	1	3	3/n	0,015
2	10	3	10	10/n	0,05
3	30	10	30	30/n	0,15
4	100	30	100	100/n	0,5
X (harsh)	Case-by-case according to the situation				

NOTE Values in A/m, r.m.s. for AC.

[a] In addition to earth magnetic field of about 20 A/m to 60 A/m, depending on location, at 1 m above ground.

[b] At 20 m from the track. The fields increase considerably the closer they get to the tracks. 1 A/m at 20 m, 1 m above ground, corresponds to a locomotive of about 3 000 kW. Some types of railway track signalling systems can also give rise to field strengths greater than level 1.

[c] For overhead lines, measured at 1 m above ground. For household or commercial environments, measured at 0,3 m from the source, the magnetic field has a range of magnitude of 1 A/m to 10 A/m.

[d] Where n is the order of the harmonic.

[e] Where audio-frequency inductive loops are present, the long-term average field strength in the frequency range 100 Hz to 5 kHz may be 0,1 A/m (level 3), see IEC 60118-4.

[f] Applicable also to railway systems with fundamental power frequencies other than 16,7 Hz.

5.2.2 Electric fields

Significant electric fields appear in the vicinity of conductive structures that have a high voltage with respect to ground potential or with respect to other conductive structures. Typical situations are for example high-voltage overhead power lines or air-insulated substations. Considering a potential impact by electric fields, cables are much less important than overhead lines due to the fact that both the metallic coating and the soil isolate the electric field nearly totally.

The electric field strength increases proportionally to the nominal voltage of the high-voltage conductors. The electric field strength at 1 m height above ground under typical high-voltage overhead lines ranges from a few kV/m to approximately 15 kV/m for voltage levels from 110 kV up to 750 kV.

Equipment that is located within buildings experiences much lower electric field strength because buildings provide a reduction factor of 10 to 20, or an even higher attenuation if such buildings are mainly constructed with conductive elements.

Electric fields caused by household appliances are generally very small and are existent in close proximity to the surface of such appliances.

Table 10 quantifies the electric fields from various low-frequency sources.

Table 10 – Disturbance degrees and levels for low-frequency electric fields

Disturbance degrees	Phenomena (sources)		
	DC lines (transmission or traction)	Railway frequency 16,7 Hz lines [a]	Power frequency 50/60 Hz lines
	Disturbance levels		
A (controlled)	Case-by-case according to the requirements		
1	0,1	0,1	≤0,1 [b]
2	1,0	0,3	≤1,0 [c]
3	10	1,0	≤10 [d]
4	20	3,0	≤20 [e]
X (harsh)	Case-by-case according to the situation		
NOTE Values in kV/m, r.m.s. for AC; values are typical for a height of 1 m above ground.			

[a] Applicable also to railway systems with fundamental power frequencies other than 16,7 Hz.
[b] Residential environment, far from overhead lines.
[c] Outdoor, below overhead lines up to 30 kV and indoor, below overhead lines up to 765 kV.
[d] Outdoor, below overhead lines up to 400 kV.
[e] In HV stations up to 400 kV and below overhead lines up to 765 kV.

NOTE 1 Information about electric field coupling is given in IEC TR 61000-2-3.

NOTE 2 There is no basic immunity standard available that reflects this kind of electromagnetic stress because significant low-frequency electric fields occur in some specific situations and the amount of electromagnetic disturbances coupled into equipment by this phenomenon is generally low so that in most cases no harmful interference is produced.

6 High-frequency electromagnetic phenomena

6.1 Conducted high-frequency phenomena

6.1.1 General

This type of disturbance is generally considered as occurring within the set of conductors of a system, either in the power supply (AC or DC) or the signal lines of the many types used in modern equipment. A frequent situation is when these systems are implemented by separate organizations or different individuals, without consideration of voltage differences that might occur between physically close conductors of different systems, hence the consideration of ground coupling path (or reference) is one of the media in which a disturbance can occur.

These disturbances can be divided into two major types, each characterized by a set of attributes, as follows:

1) continuous phenomena (induced CW) attributes:

- amplitude
- frequency
- modulation
- source impedance

} voltage and current

2) transient phenomena (unidirectional or oscillatory) attributes:

- rate of rise
- duration
- amplitude
- spectrum
- rate of occurrence
- frequency
- source impedance
- energy potential

} voltage and current

When a cable contains an imperfect external shield such as a braid, incident electromagnetic fields will induce voltages and currents (depending on loads) on the external shield relative to the ground (common mode coupling). Due to transfer impedance and admittance terms for a given cable, there can be leakage into the interior cable wiring, inducing voltages and currents (depending on loads) between pairs of wires (differential mode coupling). This simple example describes the conversion process. It should be noted that differential mode signals can also be converted to common mode signals in the reverse process, creating electromagnetic emissions from the common mode currents.

Clause 6 provides a detailed table for each of the conducted disturbances (continuous or transient) listed in Table 1. Each table gives appropriate degrees that will be selected for a definition of the environment at the various location classes.

6.1.2 Direct conducted CW phenomena

6.1.2.1 General

Equipment exists that produces direct conducted CW phenomena as a result of its functional principle or intended function. Basically, two types of conducted disturbances can be distinguished:

- Intentional signal voltages used, for example, for mains signalling, such as PLC communication. Although these voltages are intentionally generated for communication purposes, they act as potential interference sources for all the items of equipment connected to the same power supply network but are not part of the communication process.
- Unintentional disturbance voltages due to functional principles of the equipment under consideration, for example, the voltages at the switching frequency and its integer multiples in case of power electronic devices (i.e. power supplies, power drive systems, uninterruptable power supply, etc.).

The mechanisms behind the generation of those disturbances imply that they are predominantly of differential mode type as the disturbance source acts between the conductors of a supply cable. Due to the unbalanced termination of equipment involved in the generation and propagation of those disturbances common mode disturbances are also produced to a certain extent.

The levels of disturbances associated with the first type of conducted disturbances are generally limited due to the fact that corresponding communication equipment has to fulfil the requirements for maximum signal levels given in various standards. With regard to the frequency range in which these communication systems operate, two frequency ranges can be distinguished:

– below 150 kHz applied for example for mains signalling used by utilities in energy measurements or by private network users' mains communicating systems (see 5.1.4),

– above 150 kHz for example for wide band communication over the internet (see 6.1.2.3 and 6.1.2.4).

6.1.2.2 PLT

At the time of publication of this document, PLT technology is not a standardised technology, rather it is a proprietary technology developed separately by a number of manufacturers. Hence a number of key technology parameters differ between manufacturers and have been subject to some change over time and may continue to change. Such key parameters include:

– the frequencies over which the technology transmits/receives;
– the PSD at which transmission is launched onto the LV power distribution installation;
– power management ability (i.e. is the technology ‘always on’ – transmitting constantly, even when there is no data payload to transfer – or can the technology cease transmission during such times and enter a low-power mode?);
– the digital modulation scheme employed.

As PLT transmits information over lines that are designed only for power transfer and not for information transfer, the technology has the potential to disturb all radio services in the neighbourhood and in fact to cause a worldwide increase of the general background noise in this frequency range.

Generally the technology transmits over a frequency band between 1,606 5 MHz and 87,5 MHz.

Also, the technology has not yet reached the level of maturity associated with a set of open interoperability requirements: hence the only items that can be expected to interoperate are those from the same manufacturer that employ exactly the same variant.

6.1.2.3 ‘In-home’

‘In-home’ PLT systems are designed to exploit a building’s existing LV power distribution installation as a common data bus to enable the bi-directional transfer of digital data at rates up to 1 200 Mb/s. This exploitation of existing building installation is a significant benefit, as it avoids the invasive and disruptive installation of a purpose-built data transfer network and allows individual items to be networked together within the same building. The data being transferred can originate from outside the building: PLT can therefore be used to distribute high-speed internet services delivered to the building via traditional UTP telephony cable, co-axial TV cables or optical fibre connection. The data being transferred can also originate from within the building: PLT can therefore be used to allow PCs to communicate with various peripherals such as shared printing resources, shared storage resources, etc.

Transfer of data is achieved by the location of a minimum of two terminal items at power sockets connected to the LV power distribution installation.

PLT technology creates both a conducted and radiated disturbance to the local electromagnetic environment.

The first conducted disturbance arises as a result of the technology’s treatment of the LV power distribution installation as a common data bus: all other electrical and electronic items connected to the building’s LV power distribution installation will be exposed to a simultaneous common mode and differential mode conducted disturbance through the AC port. The differential mode generally dominates, as this is the intentionally launched transmission (albeit attenuated as a result of its propagation along the LV power distribution installation); the common mode disturbance is generally of a lower disturbance level, since this arises as a result of modal conversion of the launched differential mode disturbance by the unbalance about earth of the LV power distribution installation.

The second conducted disturbance arises as a result of electromagnetic coupling between a building’s internal LV power distribution installation and its telephony distribution installation: all other items connected to the building’s telephony distribution installation (i.e. voice telephony items, data modems, fax machines, etc.) will be exposed to a simultaneous common mode and differential mode conducted disturbance through the signal port. The common mode disturbance generally dominates, as this is the result of the coupling between the power and telephony distribution installation; the differential mode disturbance is generally of lower disturbance level, since this arises as a result of modal conversion of the coupled common mode disturbance by the unbalance about earth of the telephony distribution installation.

Both conducted disturbances are able to propagate along the external LV distribution and telephony installation connected to the building. Depending upon the topology of these external networks, these disturbances may be able to propagate to adjacent buildings, where it is possible that they may interfere with in-home PLT equipment from other manufacturers.

The radiated disturbance is produced by the common mode current that is induced upon the building's LV power and telephony distribution installations. This common mode disturbance is free to propagate throughout the building's distribution installation and along the external infrastructure connected to the building.

At the time of publication of this document, some proprietary techniques are under development to mitigate the impact of this radiated disturbance on broadcast reception. The techniques involve the PLT technology attempting to detect the existence of radio services within its immediate environment (by scanning the common mode or differential mode signals present on the LV power distribution installation for carriers displaying specific modulation schemes) and dynamically adjust ('notch') its launched PSD around the identified radio services. At the time of publication of this document no disturbance levels are available.

6.1.2.4 CW disturbances from infeed converters and active infeed converters (AICs)

Infeed converters and AICs are as part of their design installed and connected between the electric power supply AC and a secondary DC side. They can be found everywhere in home, residential, small office and industry environments for feeding DC consumers, for example screens, charging devices, communication units, photovoltaic converters, etc. Typically the infeed converters are installed in voltage networks with a nominal voltage of 690 V or below.

The design of infeed converters and AICs is intended to avoid low frequency harmonics by synthesizing sinusoidal AC currents. In order to achieve sinusoidal input currents the DC-link voltage is switched with a pulse frequency of normally between 300 Hz and 150 kHz. This switching generates unintended emissions of noise on the AC side.

The amount of and total emissions are dependent on several factors:

- design of the converter, especially of the filter design on the AC side
- load or no-load conditions of the connected DC side
- the number of converters on a single branch of a power supply and the degree to which their emissions differ from each other by magnitude and phase angle
- degradation of the filter capacitors because of aging
- spectrum of the emission and the frequency-dependent electromagnetic fields with inductive, capacitive and galvanic coupling to neighboring networks
- resonances in the supply network
- stability of the supply network characterized by the impedance of the supply network

Other effects which should be taken into account are non-sinusoidal input voltages resulting from other devices or from the generating unit. These will cause additional currents flowing in the capacitances within the filters of infeed converter/AIC.

The parallel installation of infeed converters can cause tripping of internal or external fuses. This results from currents within the filtering capacitors and can reach values of ten times the rated current of the infeed converter.

Infeed converters are designed to produce an AC current waveform that fulfils the emission requirements. Thus the waveform may still be significantly deformed due to the restrictions of the equipment. AICs, on the contrary, usually have quite sinusoidal current and some of them may have even active filter functionality that reduces the voltage harmonics of the supply network by producing counteracting emissions.

Side effects of infeed converters and AICs are harmonic distortions near the pulse frequency and multiples of it.

Impedances of the supply network are often assumed to be constant. In practice large hourly variations can be caused by changing loads in the network. Especially, reactive power compensating capacitors may significantly change the resonances in the network when they are switched on or off.

Power drive systems can also be equipped with an AIC. The power rating of such drives may be quite high and thus their unintended emissions may be increased similarly.

The emissions of the infeed converters can result in a relatively large bandwidth of disturbances affecting electric and electronic devices connected to the same or adjacent networks. Because the main function of converters is to convert voltages and frequencies disturbing effects may not be obvious to the user. Detailed information about emissions from power drive systems is given in IEC TS 62578. These data were used to conclude on the levels of disturbances as given in Table 11.

Table 11 – Disturbance degrees and levels of direct CW voltages

Disturbance degree	9 kHz to 150 kHz
A (controlled)	Case-by-case according to the equipment requirements
1	0,3 V
2	1 V
3	3 V
4	10 V
5	30 V
X (harsh)	Case-by-case according to the situation
NOTE 1 Values are r.m.s. NOTE 2 The corresponding immunity test is given in IEC 61000-4-19.	

6.1.2.5 Differential mode continuous wave

The disturbance sources described above predominantly generate differential mode disturbances. However, due to unbalances in the equipment and propagation, common mode disturbances are produced as well with significant conversion from differential to common mode particularly in the frequency range above 150 kHz. The situation with respect to common mode disturbances is described in 6.1.3.

For the characterization of differential mode disturbances the following aspects can be considered:

– Disturbances produced by signalling systems might reach maximum amplitudes derived from functional specification of signalling systems. Such specifications are given for example in EN 50065-1.

– Disturbances produced by power electronics can be derived from measurement data.

At this time, the collection of corresponding data is ongoing. Preliminary disturbance levels can be found in the corresponding basic immunity standard IEC 61000-4-19.

6.1.3 Induced continuous wave

Electromagnetic fields (for example produced by intentional transmitters or adjacent cabling of power electronics) induce voltages with respect to reference ground on conductors exposed to these fields. The amplitude of the induced voltage depends on the length of the conductor, its height above ground, loops formed by stray capacitances and through other equipment, plus other factors.

The relationship between the field strength and the induced voltage is nominally linear for lengths greater than a sixth of the wavelength. Resonance effects occur when the dimensions of the loop approach a quarter wavelength and multiples thereof. Table 12 gives values of induced voltages and corresponding values of common mode currents calculated by assuming a characteristic impedance with respect to a ground reference of 150 Ω (common mode impedance of the mains can be much lower than 150 Ω).

The degrees in Table 12 are for unmodulated conditions. Normally occurring disturbance signals are amplitude modulated (typically less than 80 % modulation) or frequency modulated.

Table 12 – Disturbance degrees and levels of induced CW voltages with respect to reference ground

Disturbance degree	10 kHz to 150 kHz [a] 0,15 MHz to 150 MHz	
	V	mA
A (controlled)	Case-by-case according to the equipment requirements	
1	0,3	0,7
2	1	7
3	3	21
4	10	70
5	30	210
X (harsh)	Case-by-case according to the situation	

NOTE 1 Values are r.m.s.

NOTE 2 The frequency range from 10 kHz to 150 kHz is covered by IEC 61000-4-16, 150 kHz to 80 MHz is covered by IEC 61000-4-6.

[a] Some VLF transmitters can induce considerably higher voltages in the 10 kHz to 150 kHz range.

6.1.4 Transients

For the purpose of this classification, high-frequency transient phenomena have been divided into two groups, unidirectional and oscillatory. For each group, several different phenomena (and related sources) are responsible for the occurrence of these disturbances.

1) Oscillatory transients: The relatively high frequency of oscillation of these transients ranges from less than 1 kHz (primarily capacitor switching) to several MHz (primarily local oscillations, disconnect switching). Those at the higher end of the frequency range usually have limited energy deposition capability, but can have high peak voltages. Those at the lower end of the frequency range can have higher energy deposition capability but lower peak voltages.

2) High-energy transients*:* The various waveforms of these transients are generally accepted as representing appropriate stress levels associated with nearby direct lightning discharges or switching/fuse operation:

   – lightning surges on overhead and underground distribution systems;

   – lightning surges originating on overhead lines and travelling in cables;

   – transients generated by switching and fuse operations involving trapped energy in the inductances of the power systems and related/connected equipment.

3) Very fast transients: These transients occur as single events such as electrostatic discharges (although these might involve a brief sequence of several single pulses), or as bursts associated with local low inductance load switching. Both involve very little energy but are capable of producing serious interference or upset due to the extremely fast rise time of the event. The transient bursts have been associated with arcing phenomena under the label of "showering arc" or "electrical fast transient" (EFT). Dielectric breakdown is also a source of similar high-frequency disturbances.

4) Coupled disturbances*:* Radiated waves can also be coupled into wiring systems and propagate further into equipment; at a point of use far away from the point of coupling, these disturbances then appear as conducted disturbances, although their origin is radiated energy. These coupled disturbances include several transients induced by the electromagnetic fields from a nearby (but not attached) cloud-to-ground lightning flash, which may contain 2 strokes to 20 strokes, and will contain energy in the kilohertz to megahertz frequency range. A second major source of these disturbances is due to the coupling of radiated fields from disconnect switches in power substations; these very fast rising fields induce an oscillatory voltage in cables at frequencies as high as tens of MHz.

For each waveshape selected as one of the possible representations of the transient environment, the peak open-circuit voltage and the peak short-circuit current of the source shall be stated to provide a complete and meaningful description.

Occasionally, attempts are made to describe (classify) transients in terms of "energy" to help select the rating of a candidate surge protective device. However, this concept can be a misleading oversimplification because the energy distribution among the circuit elements involved in a transient event depends on the impedance of the source (including the AC mains network) as well as on the impedance of the surge protective device called upon to divert the transient. There is no independent, meaningful, self-contained description of a transient in terms of energy alone. The energy delivered to the end equipment is the significant factor, but it depends on the distribution between the source and the load (equipment or surge-diverting protective device, or both).

Table 13 and Table 14 are structured with three sets of time scale or frequency range to recognize these diverse origins and provide a generic description of their significant attributes. The disturbance degrees are expressed as open-circuit voltages, meaning the voltage expected under typical light-load conditions, without any nearby surge protective device. For phenomena that reflect the wiring geometry and coupling modes of the transient source, the voltages are shown in V, in a first approximation, independently of the system voltage. For the switching transients (capacitor and fault clearing), the transients are directly proportional to the system voltage and, therefore, the voltages are shown as multiples of the peak value of the power frequency voltage.

Table 13 – Disturbance degrees and levels for conducted unidirectional transients in low-voltage AC power systems

Disturbance degrees	Phenomena (sources)			
	Contact arcing [a]	Lightning < 1 km [a]	Lightning > 1 km [a]	Fuse operation [b]
	Unidirectional transients time-scale			
	Nanoseconds	Microseconds		Milliseconds
	5 ns [c] 50 ns [d] Bursts [e] ms [f] 50 Ω [g]	1 µs [c] 50 µs [d] Multiple [e] ms [f] 1 Ω to 10 Ω [g]	10 µs [c] 1 000 µs [d] Multiple [e] s [f] 20 Ω to 300 Ω [g]	0,1 ms [c] 1 ms [d] Rare [e] Single [f] 0,2 Ω to 2 Ω [g]
	Disturbance levels			
A (controlled)	Case-by-case according to the equipment requirements			
1	0,5 kV	1 kV	0,5 kV	None
2	1 kV	2 kV	1 kV	0,5 U_{peak}
3	2 kV	4 kV	1,5 kV	1,0 U_{peak}
4	4 kV	8 kV	2 kV	2,0 U_{peak}
X (harsh)	Case-by-case according to the situation			

[a] Values shown are open-circuit peak voltages (that is, no large loads connected at the time of occurrence, nor any surge protective devices installed in the system) for 120 V to 690 V r.m.s. power systems. They reflect the external origin and the coupling mechanisms of these transients, which are independent of the system voltage. These are currents carried by the power conductors in the building, not the external lightning current; a direct strike to the building may cause larger currents in the power conductors.

[b] Values shown are open-circuit voltages for transients occurring at the peak of power frequency sine wave (U_{peak}), added to the power frequency voltage.
These transients which are internally generated are essentially proportional to the system voltage.

[c] Rise time. Initial rise time of the transient.

[d] Duration. Full width at half maximum of the individual transient.

[e] Rate of occurrence.

[f] Duration of event. The order of magnitude for the total duration of an event with multiple transients is expressed in the units shown.

[g] Source impedance.

Table 14 – Disturbance degrees and levels for conducted oscillatory transients in low-voltage AC power systems

Disturbance degrees	Phenomena (sources)		
	Local system response to impulsive disturbance [a]	Building response to impulsive disturbance [a]	Capacitor switching [b]
	Oscillatory transients frequency range		
	High frequency 0,5 MHz to 30 MHz	Medium frequency 5 kHz to 500 kHz	Low frequency 0,2 kHz to 5 kHz
	5 ns to 50 ns [c] 0,5 ns to 5 µs [d] Frequent [e] 50 Ω to 300 Ω [f]	0,5 µs [c] 20 µs [d] Occasional [e] 10 Ω to 50 Ω [f]	1,5 µs [c] 3 ms [d] Infrequent [e] 10 Ω to 50 Ω [f]
	Disturbance levels		
A (controlled)	Case-by-case according to the equipment requirements		
1	0,5 kV	1,0 kV	0,5 U_{peak}
2	1,0 kV	2,0 kV	1,0 U_{peak}
3	2,0 kV	4,0 kV	2,0 U_{peak}
4	4,0 kV	6,0 kV	3,0 U_{peak}
X (harsh)	Case-by-case according to the situation		

[a] Values shown are open-circuit voltages (that is, no large loads connected at the time of occurrence, nor any surge protective devices installed in the system) for 120 V to 690 V r.m.s. power systems. They reflect the external origin and the coupling mechanisms of these transients, which are essentially independent of the system voltage.

[b] Values shown are open-circuit voltages, for transients occurring at the peak of power-frequency sine wave, including the power-frequency voltage. These transients, which are internally generated, are essentially proportional to the system voltage.

[c] Rise time. Initial rise time of the first part of the transient.

[d] Duration. Full width at half maximum of the envelope of the transient.

[e] Rate of occurrence.

[f] Source impedance.

6.2 Radiated high frequency phenomena

6.2.1 General

The description of radiated electromagnetic environments is based on the evaluation of three types of phenomena, each being a category of waveforms sharing some common time domain or frequency domain properties, as follows:

– radiated (continuous wave) oscillatory disturbances;

– radiated (modulated) signal disturbances;

– radiated (transient) pulsed disturbances.

Each type contains waveforms that can be reasonably well characterized with a limited number of parameters, thanks to their similarity. A given electromagnetic phenomenon might belong to only one type, or be considered as the superposition of several waveforms belonging to different types.

A given radiated electromagnetic environment can be described with an acceptable accuracy, by using these three types, and also considering the wave impedance (near-field and far-field effects). The definition of each type is given in 6.2.2 to 6.2.4, with tables showing disturbance degrees. The rationale for splitting a single reality – the radiated electromagnetic environment at a given location – into several types, is that the action of different types on the item can have different mechanisms and different consequences. Table 15 gives an overview of the radiation sources which are considered.

Table 15 – Radiation sources

Table	Type of source
16	Radiated continuous oscillatory disturbances
17	Amateur radio bands below 30 MHz
18	27 MHz CB band
19	Analogue communication services below 30 MHz
20	Analogue communication services above 30 MHz
21, 22	Mobile and portable units of cellular phones
23, 24	Base stations of cellular phones
25	Medical and biological telemetry items
26, 27, 28	Digital television broadcast (VHF and UHF)
29, 30	Unlicensed radio services
31	Amateur radio bands above 30 MHz
32	Paging service base station
33 to 38	Other RF items
39, 40	RFID and railway transponder systems
41	Radiated pulsed disturbances
42	RADAR systems

In the past, electromagnetic fields were predominantly generated by fixed transmitters, for example by radio or TV broadcasting transmitters. Recently, handheld, frequency-modulated (FM) transceivers for business, public safety, and amateur radio communications became a significant part of those RF applications. However, distribution was limited (e.g. by licenses) and in most cases the radiating antennas were outside buildings to get a high efficiency. The situation changed once technology allowed manufacturing of compact wireless phones with low weight and a reasonable price. Wireless services (DECT, landline telephones, mobile phones, UMTS/WiFi/WiMAX/Bluetooth, baby monitors, etc.) have come into widespread use and acceptance. Recognizing the fact that equipment for these new technologies could have the antenna inside buildings and be omnipresent at work, in the home and in public transportation creates a new situation for exposure of equipment to RF energy.

With the new digital technologies, the traditional modulation format of AM and FM has given way to pulse modulation. While overall time-averaged transmit power levels might have generally decreased over time due to improved network density and migration of services, the maximum possible (peak pulse) power levels in other bands have increased significantly. Moreover, the incorporation of multiple transmitting antennas (to support for example WiFi and Bluetooth links), evolving form factors, higher bit rates to facilitate data transfer and Internet access and the use of wireless headsets have resulted in a more complex and diverse pattern of use and exposure.

With respect to the exposure to those various types of electromagnetic fields, two situations have to be distinguished: equipment is exposed to an electromagnetic field under far field conditions or under near-field conditions, respectively. The second situation in particular has increased significantly in the recent past. Hence Tables 16 to 19, giving disturbance levels for various types of transmitters, consider both situations.

It should be noted, that the well-established immunity test method in the basic immunity standard IEC 61000-4-3 simulates the thread due to electromagnetic fields mostly under far field conditions. However, it turned out that equipment could have different immunity characteristics for exposure under near-field conditions. A corresponding immunity test method is currently being worked out in the framework of the basic immunity standard IEC 61000-4-39.

6.2.2 Radiated continuous oscillatory disturbances

These disturbances, occurring as single or multiple events, can strongly couple with the item, because of an intentional selectivity, or because of an unintentional resonant coupling mechanism. The values encountered in practice strongly depend on the distance between victim and source (see Table 16 and Annex B for more information). Disturbances from modulated sources (e.g. mobile phones, CB radio) are dealt with in 6.2.3.

Table 16 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Radiated continuous oscillatory disturbances

Disturbance degree and corres-ponding field strength	**Phenomena (sources)**		
	ISM Group 2 equipment	ISM Group 2 equipment	ISM Group 2 equipment
	Transmitter frequencies [MHz]		
	6,765 to 6,795 [a] 13,553 to 13,567 26,957 to 27,283	40,66 to 40,70 433,05 to 434,79 [a] 902 to 928	2 400 to 2 500 5 725 to 5 875 24 000 to 24 250 61 000 to 61 500 [a] 122 000 to 123 000 [a] 244 000 to 246 000 [a]
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 0,3 V/m	*d* [b]	*d* [b]	*d* [b]
2 1 V/m	*d* [b]	*d* [b]	*d* [b]
3 3 V/m	*d* [b]	*d* [b]	*d* [b]
4 10 V/m	*d* [b]	*d* [b]	*d* [b]
5 30 V/m	*d* [b]	*d* [b]	*d* [b]
X (harsh)	Case-by-case according to the situation		

[a] There are no limits for those frequencies and frequency bands for radiated disturbances (see CISPR 11).

[b] ISM group 2 equipment (according to CISPR 11) is not limited in the power used for the operation and therefore there are no limits to be observed for radiated disturbances with regard to EMC. Hence it is not possible to generally calculate distances *d*.

6.2.3 Radiated modulated disturbances

6.2.3.1 Radiated modulated disturbances below 30 MHz

Electromagnetic fields below 30 MHz are mainly due to the usage of amateur radio systems, CB equipment and AM broadcasting.

The power values mentioned in Table 17 are a summary of all frequencies and the maximum allowed output power of the transmitter given as P_{PEP} (peak envelope power) of all three ITU regions. The output power used for the calculation of the distances in the table is P_{PEP} multiplied by the theoretical antenna gain of a half-wavelength dipol antenna (2,15 dB) and is given as P_{EIRP} (equivalent isotropically radiated power). Possible losses from cables, switches and mismatches are not considered, to keep the model as simple as possible. The calculated field strength is only valid for the main beam of the antenna and is lower outside this beam.

The distances may vary in real situations because the typical antenna gain is different (up to 10 dB or more) and losses (e.g. from cables) have to be taken into account. These (mostly rotatable) high gain antennas are normally mounted on antenna towers 10 m to 30 m above ground or on a roof. In this case only in the direction of the main beam of the antenna the full field strength will occur. Even for slight deviations from the direction of maximum beam strength significant reductions of the antenna gain are observed.

Table 17 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Amateur radio bands below 30 MHz

Disturbance degree and corres-ponding field strength	**Phenomena (sources)**		
	Amateur radio station P = 1 W_{ERP}	Amateur radio station P = 100 W_{PEP} [a] P_{EIRP} ≈ 164 W [a] (for 5 MHz band P = 50 W_{ERP}) [e]	Amateur radio station P = 1 500 W_{PEP} [a] P_{EIRP} ≈ 2 500 W [a]
	Transmitter frequencies [MHz]		
	0,135 7 to 0,135 8 [b] 0,135 7 to 0,137 8 [c] 0,472 to 0,479 [d]	1,8 to 2,0 3,5 to 4,0 5,330 5; 5,366 5, 5,371 5; 5,403 5 7,0 to 7,3 10,1 to 10,157 3 14,0 to 14,350 18,068 to 18,168 21,0 to 21,45 24,890 to 24,990 28,0 to 29,7	1,8 to 2,0 3,5 to 4,0 5,330 5; 5,366 5, 5,371 5; 5,403 5 7,0 to 7,3 10,1 to 10,157 3 14,0 to 14,350 18,068 to 18,168 21,0 to 21,45 24,890 to 24,990 28,0 to 29,7
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 0,3 V/m	d [b]	233	905
2 1 V/m	d [b]	70	271
3 3 V/m	d [b]	23	90,5
4 10 V/m	d [b]	7	27,1
5 30 V/m	d [b]	2,3	9,05
X (harsh)	Case-by-case according to the situation		

NOTE The above mentioned power and frequency bands are a summary of all three ITU regions. The power P is (if not otherwise mentioned) the allowed maximum output power of the amplifier (P_{PEP}). The power arriving at the antenna and effectively radiated by it is P_{ANT} and is P reduced by the losses of the feeding cable. For easy calculation of E and d, the effective isotropic power P_{EIRP} is useful. Most antennas have a direction with maximum radiation, i.e. in that direction they have a certain antenna gain G_{ISO} compared to an isotropic radiator. E and d of this maximum radiation can be easily calculated by means of P_{EIRP}, which is obtained by multiplying P_{ANT} by the isotropic antenna gain G_{ISO}. d is the spatial distance from the antenna.

In case of an amateur radio station many antenna types (and resulting antenna gains) are possible. The calculations for frequencies above 1,8 MHz in this table are done with an antenna gain of G_{ISO} = 2,15 dBi of a half-wavelength dipole antenna and assuming a lossless feeding cable.

Higher gains are possible, but these (mostly rotatable) antenna types are normally mounted on antenna towers 10 m to 30 m above ground. Typical values for G_{ISO} of such antennas are between 2 dBi and 10 dBi. In this case only in the direction of the main beam of the antenna the full field strength will occur. In other directions the field strength will be considerably reduced.

The same values for P_{EIRP} and therefore for E and d in the beam direction for the strong amateur station in the rightmost column could also be obtained with P = 500 W, a feeding cable attenuation of 1,5 dB and a directional antenna with an isotropic antenna gain G_{ISO} of 8,5 dBi. With the same P_{EIRP} the disturbing probability of such an antenna is much lower than that of an omnidirectional antenna, because the beam width is limited in the horizontal and vertical plane.

[a] To simplify the table the highest frequency for each column is used in the calculation of the distance. For frequencies below 7 MHz the result may be incorrect because the calculations are done for far field conditions.

[b] For this frequency band no calculations are done. The distances for 1 W_{ERP} (equivalent radiated power = standardized theoretical transmitting power taking into account system losses and antenna gain) are always in the near field and strongly depend on the antenna type used for transmission. Due to this fact the distances should be investigated case by case from measurements.

[c] In Australia.

[d] In Australia; used with P = 5 W_{ERP}

[e] For this frequency band no calculations are done to keep the table simple. The distances are much closer. The formulae in Annex B could be used to do the calculations if needed.

Table 18 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – 27 MHz CB band

Disturbance degree and corres-ponding field strength		Phenomena (sources)	
		CB mobile / portable P = 4 W (AM, FM) P = 12 W_{PEP} (SSB)	CB fixed installation P = 4 W (AM, FM) P = 12 W_{PEP} (SSB)
		Transmitter frequencies [MHz]	
		26,560 to 27,991	26,560 to 27,991
		Distance to source [m]	
A	(controlled)	Case-by-case according to the equipment requirements	
1	0,3 V/m	63,2	80,5
2	1 V/m	18,9	24
3	3 V/m	6,32	8,1
4	10 V/m	1,89	2,4
5	30 V/m	0,63	0,81
X	(harsh)	Case-by-case according to the situation	

NOTE The above mentioned power and frequency bands are a summary of all three ITU regions. In case of a CB radio station (fixed installation) many antenna types (and resulting antenna gains) are possible. The calculations are done with an antenna gain of 0 dB (0 dBi) for a mobile transmitter and with 2,15 dB (0 dBd) for a fixed station.

Table 19 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Analogue communication services below 30 MHz

Disturbance degree and corres-ponding **field strength**	**Phenomena (sources)**
	AM broadcasting P = 500 kW
	Transmitter frequencies [MHz]
	0,150 to 30
	Distance to source [m]
A (controlled)	Case-by-case according to the equipment requirements
1 0,3 V/m	16 500
2 1 V/m	4 959
3 3 V/m	1 650
4 10 V/m	430
5 30 V/m	378,5
X (harsh)	Case-by-case according to the situation

NOTE The distances are derived assuming an antenna gain of 2,15 dBi of a half wavelength dipole antenna and at the lowest frequency. The table provides data for the frequency range 0,150 MHz to 30 MHz for a 500 kW transmitter. Other power levels (50 kW to 2 500 kW) and antenna types (and resulting antenna gains) are also possible.

6.2.3.2 Radiated modulated disturbances above 30 MHz

Radiated electromagnetic fields from digital equipment such as cellular phones, digital television broadcast, and wireless LANs (local area networks) can be categorized to continuous and modulated disturbances. The broadcast services caused by the digital dividend after digital television transition are also categorized to this disturbance. Radiated disturbances of interest in 6.2.3.2 are classified into pulsed disturbances such as a spread spectrum and multi-carrier disturbances such as an OFDM (orthogonal frequency division multiplexing). A part of the modulation may be due to very frequent (several times per second) adjustments of the transmit power or due to the use of time domain multiple access (TDMA). In this last example the modulated carrier is active in short bursts resulting in a 100 % AM envelope repeated several times per second. A modulated disturbance has both the pulse and the oscillatory characteristics. A common factor is a continuous signal. Table 20 to Table 38 give information about various radiation sources and the connected range of disturbance degrees.

Further technical details about the various radiation sources are given in Annex B.

Table 20 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Analogue communication services above 30 MHz

Disturbance degree and corres-ponding field strength	Phenomena (sources)			
	Walkie-talkie P = 5 W	TV – VHF P = 320 kW	FM broadcast P = 100 kW	TV – UHF P = 500 kW
	Transmitter frequencies [MHz]			
	30 to 1 000	48 to 223	76 to 108	470 to 853
	Distance to source [m]			
A (controlled)	Case-by-case according to the equipment requirements			
1 0,3 V/m	40,7	13 220	7 390	16 500
2 1 V/m	12,2	3 965	2 216	4 950
3 3 V/m	4,1	1 322	739	1 650
4 10 V/m	1,22	396,5	221,6	495
5 30 V/m	0,41	132,2	73,9	165
X (harsh)	Case-by-case according to the situation			

NOTE 1 The distances for all fixed services are derived assuming an antenna gain of 2,15 dBi of a half wavelength dipole antenna and at the lowest frequency. The data provided in the table represent typical analogue communication services. Different antenna types (and resulting antenna gains) are possible.

NOTE 2 The distances for the mobile service (walkie-talkie) are derived assuming an antenna gain of 0 dBi of an isotropic antenna at the lowest frequency.

Table 21 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Mobile and portable phones

Disturbance degree and corres-ponding field strength	Phenomena (sources)						
	GSM P = 2 W (portable) P = 20 W (obile)	DCS1800 P = 4 W	DECT P = 0,25 W	CT-2 P = 0,01 W	PHS P = 0,08 W	NADC P = 6 W	IMT-2000 (TDD) (FDD) P = 0,25 W
	Transmitter frequencies [MHz]						
	890 to 915	1 710 to 1 784	1 880 to 1 960	864 to 868	1 895 to 1 918	825 to 845	1 900 to 1 980
	Distance to source [m]						
A (controlled)	Case-by-case according to the equipment requirements						
1 0,3 V/m	104	47	12	2,3	6,6	58	12
2 1 V/m	31	14	3,5	0,7	2,0	16	3,5
3 3 V/m	10,5	4,7	1,2	0,23	0,66	5,7	1,2
4 10 V/m	3,2	1,4	0,35	0,063	0,2	1,6	0,35
5 30 V/m	1,1	0,47	0,12	0,04	0,061	0,57	0,11
6 100 V/m	0,31	0,14	0,031	0,027	0,023	0,17	0,031
X (harsh)	Case-by-case according to the situation						

NOTE 1 The output power, P, of each mobile or portable cellular is indicated by the maximum burst power, which means the average power within the burst signal.

NOTE 2 The calculation of distances is done with the maximum power indicated for that type of source.

Table 22 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Mobile and portable phones (continued)

Disturbance degree and corresponding field strength	Phenomena (sources)				
	3G/UMTS P = 21 dBm = 126 mW	3G/FOMA P = 24 dBm = 251 mW	3.5G/HSPA P = 24 dBm = 251 mW	3.9G/LTE P = 24 dBm = 251 mW	4G/LTE-A P = 23 dBm = 200 mW
	Transmitter frequencies [MHz]				
	a	b	c	d	450 to 470 698 to 862 790 to 862 2 300 to 2 400 3 400 to 3 600
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	8,3	12	12	12	10
2 1 V/m	2,5	3,5	3,5	3,5	3,1
3 3 V/m	0,83	1,2	1,2	1,2	1
4 10 V/m	0,24	0,34	0,34	0,34	0,29
5 30 V/m	0,073	0,1	0,11	0,1	0,11
6 100 V/m	0,044	0,047	0,045	0,047	0,067
X (harsh)	Case-by-case according to the situation				

NOTE 1 The output power, P, of each mobile or portable cellular is indicated by the maximum burst power, which means the average power within the burst signal.

NOTE 2 The calculation of distances is done with the maximum power indicated for that type of source.

NOTE 3 The frequency allocation and transmitting power of 5G (5th generation mobile networks) is not determined yet because no international 5G development projects, such as 3GPP, have officially been launched. The standard for 5G will be released in the early 2020s. In 5G, broadband of around 1 GHz and a frequency allocation in the sub-millimeter band (e.g. 20 GHz) are considered. This table can be used to estimate the disturbance degrees of 5G cellular.

[a] Band II: 1 850 MHz to 1 910 MHz (uplink), 1 930 MHz to 1 990 MHz (downlink), US, CA
Band IV: 1 710 MHz to 1 785 MHz (uplink), 2 110 MHz to 2 155 MHz (downlink), US
Band V: 824 MHz to 849 MHz (uplink), 869 MHz to 894 MHz (downlink), US, AU, CA, BR
Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink), FI, TH, AU, JP
Band XI: 1 427,9 MHz – 1 447,9 MHz (uplink), 1 475,9 MHz – 1 495,9 MHz (downlink),JP
Band XIII: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink), US (planned)
Band XIV: 788 MHz to 798 MHz (uplink), 758 MHz to 768 MHz (downlink),US (planned)
Band XX: 832 MHz to 862 MHz (uplink), 791 MHz to 821 MHz (downlink), EU

[b] Band I: 1 920 MHz to 1 980 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), JP
Band VI: 830 MHz to 840 MHz (uplink), 875 MHz to 885 MHz (downlink), JP
Band IX: 1 749,9 MHz to 1 784,9 (uplink), 1 844,9 MHz to 1 879,9 (downlink), JP

[c] Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink)
Band IX: 1 749,9 MHz to 1 784,9 (uplink), 1 844,9 MHz to 1 879,9 (downlink)
Band XI: 1 427,9 MHz to 1 447,9 MHz (uplink), 1 475,9 MHz to 1 495,9 MHz (downlink)

[d] Band I: 1 920 MHz to 1 980 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), JP, KR
Band II: 1 850 MHz to 1 910 MHz (uplink), 1 930 MHz to 1 990 MHz (downlink), CA, Central and South America
Band III: 1 710 MHz to 1 785 MHz (uplink), 1 805 MHz to 1 880 MHz (downlink), JP (planned), HK, KR, EU
Band IV: 1 710 MHz to 1 785 MHz (uplink), 2 110 MHz to 2 155 MHz (downlink), US
Band V: 824 MHz to 849 MHz (uplink), 869 MHz to 894 MHz (downlink), KR
Band VII: 2 500 – 2 570 MHz (uplink), 2 620 MHz to 2 690 MHz (downlink), North Europe, HK, CN, CA, Central and South America
Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink), JP, KR, EU, Central and South America
Band X: 1 710 MHz to 1 770 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), EC, PE, UY
Band XI: 1 427,9 MHz to 1 447,9 MHz (uplink), 1 475,9 MHz to 1 495,9 MHz (downlink),JP
Band XII: 699 MHz to 716 MHz (uplink), 729 MHz to 746 MHz (downlink), US
Band XIII: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink), US (planned)
Band XIV: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink),US (planned)
Band XVII: 704 MHz to 716 MHz (uplink), 734 MHz to 746 MHz (downlink), US
Band XVIII: 815 MHz to 830 MHz (uplink), 860 MHz to 875 MHz (downlink), JP
Band XIX: 830 MHz to 845 MHz (uplink), 875 MHz to 890 MHz (downlink), JP
Band XX: 832 MHz to 862 MHz (uplink), 791 MHz to 821 MHz (downlink), EU
Band XXI: 1 447,9 MHz to 1 462,9 MHz (uplink), 1 495,9 MHz to 1 510,9 MHz (downlink),JP
Band XXIII: 2 000 MHz to 2 020 MHz (uplink), 2 180 MHz to 2 220 MHz (downlink),US
Band XXIV: 1 626,5 MHz to 1 660,5 MHz (uplink), 1 525 MHz to 1 559 MHz (downlink),US
Band XXV: 1 850 MHz to 1 915 MHz (uplink), 1 930 MHz to 1 995 MHz (downlink),US
Band XXVI: 814 MHz to 849 MHz (uplink), 859 MHz to 894 MHz (downlink), US
Band XXVIII: 703 MHz to 748 MHz (uplink), 758 MHz to 803 MHz (downlink), JP, AU, Central and South America
Band XXXVIII: 2 570 MHz to 2 620 MHz (uplink/downlink), EU
Band XL: 2 300 MHz to 2 400 MHz (uplink/downlink), AU, CN, IN
Band XLI: 2 496 MHz to 2 690 MHz (uplink/downlink), US, CN

Table 23 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Base stations

Disturbance degree and corres-ponding field strength	**Phenomena (sources)**						
	GSM P = 320 W$_{ERP}$	DCS1800 P = 200 W$_{ERP}$	DECT P = 0,25 W$_{ERP}$	CT-2 P = 0,25 W$_{ERP}$	PHS P = 0,5 W$_{ERP}$	NADC P = 500 W$_{ERP}$	IMT-2000 (TDD) (FDD) P = 20 W$_{ERP}$
	Transmitter frequencies [MHz]						
	935 to 960	1 805 to 1 880	1 880 to 1 960	864 to 868	1 895 to 1 918	870 to 890	1 900 to 1 920 2 110 to 2 170
	Distance to source [m]						
A (controlled)	Case-by-case according to the equipment requirements						
1 0,3 V/m	2 060	1 630	57	57	81	2 590	520
2 1 V/m	620	490	17	17	25	770	155
3 3 V/m	206	163	5,7	5,7	8,1	259	52
4 10 V/m	62	49	1,7	1,7	2,5	77	15,5
5 30 V/m	21	16	0,57	0,57	0,81	26	5,1
6 100 V/m	6,2	4,9	0,17	0,17	0,24	7,7	1,5
X (harsh)	Case-by-case according to the situation						

NOTE The output power, P, of each base station is indicated by the maximum burst power, which means the average power within the burst signal. An absolute gain of each base-station antenna is assumed to be 16,0 dBi. For instance, the case where there is a base station in a roof of a building is assumed. The fields are also calculated from Formula (B.4) in Annex B. In practice the resulting field strength can be much lower due to the placement and high directivity of the transmitting antennas.

Table 24 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Base stations (continued)

Disturbance degree and corres-ponding field strength		Phenomena (sources)				
		3G/UMTS *P* = 400 W (maximum value)	3G/FOMA *P* = 20 W	3.5G/HSPA *P* = 20 W	3.9G/LTE *P* = 10 W	4G/LTE-A *P* = 10 W
		Transmitter frequencies [MHz]				
		a	b	c	d	450 to 470 698 to 862 790 to 862 2 300 to 2 400 3 400 to 3 600
		Distance to source [m]				
A	(controlled)	Case-by-case according to the equipment requirements				
1	0,3 V/m	2 304	515	515	364	364
2	1 V/m	691	154	154	109	109
3	3 V/m	230	51,5	51,5	36	36
4	10 V/m	69	15,4	15,4	10,9	10,9
5	30 V/m	23	5,15	5,15	3,7	3,6
6	100 V/m	6,9	1,54	1,54	1,09	1,08
X	(harsh)	Case-by-case according to the situation				

NOTE 1 The output power, *P*, of each base station is indicated by the maximum burst power, which means the average power within the burst signal. An absolute gain of each base-station antenna is assumed to be 16,0 dBi. For instance, the case where there is a base station in a roof of a building is assumed. The fields are also calculated from Formula (B.4) in Annex B. In practice the resulting field strength can be much lower due to the placement and high directivity of the transmitting antennas.

NOTE 2 The frequency allocation and transmitting power of 5G (5th generation mobile networks) is not determined yet because no international 5G development projects, such as 3GPP, have officially been launched. The standard for 5G will be released in the early 2020s. In 5G, broadband of around 1 GHz and a frequency allocation of sub-millimeter band (e.g. 20 GHz) are considered. At this moment, Table 23 can be used to estimate the disturbance degrees of 5G base station.

[a] Band II: 1 850 MHz to 1 910 MHz (uplink), 1 930 MHz to 1 990 MHz (downlink), US, CA
Band IV: 1 710 MHz to 1 785 MHz (uplink), 2 110 MHz to 2 155 MHz (downlink), US
Band V: 824 MHz to 849 MHz (uplink), 869 MHz to 894 MHz (downlink), US, AU, CA, BR
Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink), FI, TH, AU, JP
Band XI: 1 427,9 MHz to 1 447,9 MHz (uplink), 1 475,9 MHz to 1 495,9 MHz (downlink),JP
Band XIII: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink), US (planned)
Band XIV: 788 MHz to 798 MHz (uplink), 758 MHz to 768 MHz (downlink),US (planned)
Band XX: 832 MHz to 862 MHz (uplink), 791 MHz to 821 MHz (downlink), EU

[b] Band I: 1 920 MHz to 1 980 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), JP
Band VI: 830 MHz to 840 MHz (uplink), 875 MHz to 885 MHz (downlink), JP
Band IX: 1 749,9 MHz to 1 784,9 (uplink), 1 844,9 MHz to 1 879,9 MHz (downlink), JP

[c] Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink)
Band IX: 1 749,9 MHz to 1 784,9 MHz (uplink), 1 844,9 MHz to 1 879,9 (downlink)
Band XI: 1 427,9 MHz to 1 447,9 MHz (uplink), 1 475,9 MHz to 1 495,9 MHz (downlink)

[d] Band I: 1 920 MHz to 1 980 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), JP, KR
Band II: 1 850 MHz to 1 910 MHz (uplink), 1 930 MHz to 1 990 MHz (downlink), CA, Central and South America
Band III: 1 710 MHz to 1 785 MHz (uplink), 1 805 MHz to 1 880 MHz (downlink), JP (planned), HK, KR, EU
Band IV: 1 710 MHz to 1 785 MHz (uplink), 2 110 MHz to 2 155 MHz (downlink), US
Band V: 824 MHz to 849 MHz (uplink), 869 MHz to 894 MHz (downlink), KR
Band VII: 2 500 MHz to 2 570 MHz (uplink), 2 620 MHz to 2 690 MHz (downlink), North Europe, HK, CN, CA, Central and South America
Band VIII: 880 MHz to 915 MHz (uplink), 925 MHz to 960 MHz (downlink), JP, KR, EU, Central and South America
Band X: 1 710 MHz to 1 770 MHz (uplink), 2 110 MHz to 2 170 MHz (downlink), EC, PE, UY
Band XI: 1 427,9 MHz to 1 447,9 MHz (uplink), 1 475,9 MHz to 1 495,9 MHz (downlink), JP
Band XII: 699 MHz to 716 MHz (uplink), 729 MHz to 746 MHz (downlink), US
Band XIII: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink), US (planned)
Band XIV: 777 MHz to 787 MHz (uplink), 746 MHz to 756 MHz (downlink),US (planned)
Band XVII: 704 MHz to 716 MHz (uplink), 734 MHz to 746 MHz (downlink), US
Band XVIII: 815 MHz to 830 MHz (uplink), 860 MHz to 875 MHz (downlink), JP
Band XIX: 830 MHz to 845 MHz (uplink), 875 MHz to 890 MHz (downlink), JP
Band XX: 832 MHz to 862 MHz (uplink), 791 MHz to 821 MHz (downlink), EU
Band XXI: 1 447,9 MHz to 1 462,9 MHz (uplink), 1 495,9 MHz – 1 510,9 MHz (downlink), JP
Band XXIII: 2 000 MHz to 2 020 MHz (uplink), 2 180 MHz to 2 220 MHz (downlink), US
Band XXIV: 1 626,5 MHz to 1 660,5 MHz (uplink), 1 525 MHz to 1 559 MHz (downlink), US
Band XXV: 1 850 MHz to 1 915 MHz (uplink), 1 930 MHz to 1 995 MHz (downlink), US
Band XXVI: 814 MHz to 849 MHz (uplink), 859 MHz to 894 MHz (downlink), US
Band XXVIII: 703 MHz to 748 MHz (uplink), 758 MHz to 803 MHz (downlink), JP, AU, Central and South America
Band XXXVIII: 2 570 MHz to 2 620 MHz (uplink/downlink), EU
Band XL: 2 300 MHz to 2 400 MHz (uplink/downlink), AU, CN, IN
Band XLI: 2 496 MHz to 2 690 MHz (uplink/downlink), US, CN

Table 25 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Medical and biological telemetry items

Disturbance degree and corresponding field strength		Phenomena (sources)			
		Tele-control (JP) P = 10 mW_{ERP}	Medical telemetry (JP) P = 10 mW_{ERP}	Wireless medical telemetry service (WMTS) (US) E = 0,2 V/m at 3 m [a]	Medical telemetry (ISM) P = 200 mW_{ERP}
		Transmitter frequencies [MHz]			
		426,025 to 469,487 5	420,05 to- 449,525	608 to 614	40,68
		Distance to source [m]			
A	(controlled)	Case-by-case according to the equipment requirements			
1	0,3 V/m	2,3	2,3	1,9	10
2	1 V/m	0,69	0,69	0,58	2,9
3	3 V/m	0,21	0,21	0,18	1,1
4	10 V/m	0,09	0,09	0,069	0,72
5	30 V/m	0,062	0,063	0,047	0,51
X	(harsh)	Case-by-case according to the situation			

NOTE Medical implant devices are not included. An absolute gain of each antenna connecting with the item is assumed to be 2,14 dBi maximum. The fields are also calculated from Formula (B.4) in Annex B.

[a] Transmitting power is converted from the electric field strength 0,2 V/m at the distance of 3 m by using Formula (B.4) in the near-field condition as 11,5 mW. Each separation distance for each field-strength is calculated using the transmitting power using also Formula (B.4).

Table 26 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Digital-television broadcast (VHF)

Disturbance degree and corresponding field strength	Phenomena (sources)				
	Digital TV broadcast $P = 100\ \text{kW}_{\text{ERP}}$	Digital TV broadcast $P = 100\ \text{kW}_{\text{ERP}}$	Digital TV broadcast $P = 325\ \text{kW}_{\text{ERP}}$	Digital TV broadcast $P = 50\ \text{kW}_{\text{ERP}}$(SW)	Digital TV broadcast $P = 10\ \text{kW}_{\text{ERP}}$(DE)
	Countries				
	US [a], CA [a], BR [b]	US [a], CA [a], BR [b]	US [a], CA [a], BR [b], NL [c]	AU [c], FR [c], FI [c], DK [c], SW [c], IT [c]	PT [c], IE [c], DE [c], NO [c]
	Transmitter frequencies [MHz]				
	54 to 72	76 to 88	174 to 216	174 to 230	174 to 202/209/239/240
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	180	180	330	130	58
2 1 V/m	55	55	99	38	17
3 3 V/m	18	18	33	13	5,8
4 10 V/m	5,4	5,4	9,9	3,9	17,3
5 30 V/m	1,7	1,7	3,2	1,3	5,8
6 100 V/m	0,66	0,56	0,96	0,33	1,73
X (harsh)	Case-by-case according to the situation				

NOTE For instance, the case where a set of transmitting antennas is installed in a broadcasting tower. The antenna installation height of the transmitting antenna is assumed to be about 300 m. The fields are also calculated from Formula (B.4) in Annex B. A directivity of –30° elevation is –30 dB smaller than that of the maximum value. The attenuation includes an attenuation caused by the cross-polarization and the radiation pattern of the transmitting antenna. For example, although the electric field is 100 V/m at the point located on the boresight, the field at the observation point is 3,16 V/m.

[a] Transmission scheme of DTV: ATSC (Advanced Television Systems Committee)

[b] Transmission scheme of DTV: ISDB-T (Integrated Services Digital Broadcasting – Terrestrial)

[c] Transmission scheme of DTV: DVB-T (Digital Video Broadcasting – Terrestrial)

Table 27 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Digital-television broadcast (UHF)

Disturbance degree and corres-ponding field strength	Phenomena (sources)				
	Digital TV broadcast P = 48 kW_{ERP}	Digital TV broadcast P = 5 kW_{ERP}	Digital TV broadcast P = 50 kW_{ERP}(FI)	Digital TV broadcast P = 120 kW_{ERP}(DE)	Digital TV broadcast P = 1 000 kW_{ERP}
	Countries				
	JP [b]	KR [a] HK	FR [c], FI [c], IT [c]	IE [c], ES [c], PT [c], DE [c], DK [c], NL [c], SW [c], NO [c]	US [a], CA [a]
	Transmitter frequencies [MHz]				
	470 to 710	470 to 752/806	470 to 830/790/854	470 to 862	470 to 608, 614 to 698
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	128	41	129	200	577
2 1 V/m	38	12	39	60	174
3 3 V/m	12,7	4,1	12,9	20	57,7
4 10 V/m	3,8	1,2	3,9	6	17,3
5 30 V/m	1,26	0,4	1,3	2	5,8
6 100 V/m	0,37	0,11	0,38	0,59	1,73
X (harsh)	Case-by-case according to the situation				

NOTE For instance, the case where a set of transmitting antennas is installed in a broadcasting tower. The antenna installation height of the transmitting antenna is assumed to be about 300 m. The fields are also calculated from Formula (B.4) in Annex B. A directivity of –30° elevation is –30 dB smaller than that of the maximum value. The attenuation includes an attenuation caused by the cross-polarization and the radiation pattern of the transmitting antenna. For example, although the electric field is 100 V/m at the point located on the boresight, the field at the observation point is 3,16 V/m.

[a] Transmission scheme of DTV: ATSC (Advanced Television Systems Committee)

[b] Transmission scheme of DTV: ISDB-T (Integrated Services Digital Broadcasting – Terrestrial)

[c] Transmission scheme of DTV: DVB-T (Digital Video Broadcasting – Terrestrial)

Table 28 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Digital-television broadcast (UHF) (continued)

Disturbance degree and corres-ponding field strength	Phenomena (sources)				
	Digital TV broadcast P = 48 kW_{ERP}	Digital TV broadcast P = 5 kW_{ERP}	Digital TV broadcast P = 50 kW_{ERP}(FI)	Digital TV broadcast P = 120 kW_{ERP}(DE)	Digital TV broadcast P = 1 000 kW_{ERP}
	Countries				
	BR [b]	UK [c]	SG [c]	AU [c]	TW [c]
	Transmitter frequencies [MHz]				
	470 to 608, 614 to 806	470 to 550, 630 to 806	494 to 790	520 to 610, 750 to 806	530 to 602
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	163	258	115	258	167
2 1 V/m	49	77	35	77	50
3 3 V/m	16,4	25,8	11,5	25,8	16,7
4 10 V/m	4,9	7,7	3,4	7,7	5
5 30 V/m	1,63	2,58	1,15	2,58	1,67
6 100 V/m	0,48	0,77	0,34	0,77	0,49
X (harsh)	Case-by-case according to the situation				

NOTE 1 For instance, the case where a set of transmitting antennas is installed in a broadcasting tower. The antenna installation height of the transmitting antenna is assumed to be about 300 m. The fields are also calculated from Formula (B.4) in Annex B. A directivity of –30° elevation is –30 dB smaller than that of maximum value. The attenuation includes an attenuation caused by the cross-polarization and the radiation pattern of the transmitting antenna. For example, although the electric field is 100 V/m at the point located on the boresight, the field at the observation point is 3,16 V/m.

NOTE 2 An absolute gain of the transmitting antenna for DTV of Taiwan is assumed to be 12,25 dBi.

[a] Transmission scheme of DTV: ATSC (Advanced Television Systems Committee)

[b] Transmission scheme of DTV: ISDB-T (Integrated Services Digital Broadcasting – Terrestrial)

[c] Transmission scheme of DTV: DVB-T (Digital Video Broadcasting – Terrestrial)

The digital dividend refers to the spectrum which is released in the process of digital television transition. The digital dividend usually locates at frequency bands from 174 MHz to 230 MHz (VHF) and from 470 MHz to 862 MHz (UHF). In the case of Japan the frequency band from 90 MHz to 108 MHz (VHF low-band) also is added. Current status of the digital dividend around the world is listed below.

US: A frequency band from 698 MHz to 806 MHz is divided up into A, B, C, D, and E blocks. These frequency blocks are to be auctioned.

EU: Frequency bands of 800 MHz and 900 MHz are mainly to be allocated for 3G/4G cellular phones.

JP: Ministry of Internal Affairs and Communications sets out a policy for the division and reallocations of the frequency band. Services of ITS (intelligent transport systems) for road-to-vehicle and vehicle-to-vehicle communications, FPU (field pickup units) for broadcasting system, and radio microphones will be allowed in a frequency band from 755 MHz to 806 MHz.

Table 29 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Unlicensed radio services

Disturbance degree and corresponding field strength	Phenomena (sources)				
	Radio microphones P = 10 mW_{ERP}	Radio control radio service P = 0,75 W_{EIRP}	Family radio service (FRS) P = 0,5 W_{ERP}	Low power radio service (LPRS) P = 0,1 W_{EIRP}	Multi-use radio service (MURS) P = 2 W [a]
	Countries				
	JP	US	US	US	US
	Transmitter frequencies [MHz]				
	74,322; 806,125 to 809,75	72,75	462 to 467	216	151; 154
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	2,3	16	17	5,7	37
2 1 V/m	0,69	4,7	5	1,7	11
3 3 V/m	0,22	1,5	1,7	0,54	3,7
4 10 V/m	0,065	0,56	0,48	0,20	1,1
5 30 V/m	0,041	0,38	0,14	0,14	0,34
X (harsh)	Case-by-case according to the situation				

NOTE 1 Radio microphones, wireless telemetries, radio control radio services, citizens band radio services, personal wireless communications, cordless phones, and other short range devices are categorized in the table. However, wireless telemetries and citizens band radio services are not treated here. Some frequencies of MURS and FRS allocate for cordless phones. The fields are also calculated from Formula (B.4) in Annex B.

NOTE 2 The relationship between effective radiated power (ERP) and equivalent isotropic radiated power (EIRP) is P_{EIRP} = 1,64 × P_{ERP}.

[a] 2 W is the transmitter power output; the antenna gain is 3,0 dBi.

Table 30 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Unlicensed radio services (continued)

Disturbance degree and corresponding **field strength**	**Phenomena (sources)**						
	Non-specific SRD P = 10 mW_{ERP}	Non-specific SRD P = 0,5 W_{ERP}	Alarm SRDs P = 25 mW_{ERP}	Model control SRDs E = 0,1 W_{ERP}	Wireless Audio SRDs P = 10 mW_{ERP}	PMR 446 equipment P =0,5 W_{ERP}	Digital PMR 446 equipment P = 0.5 W_{ERP}
	Countries						
	EU	EU	EU	EU	EU	EU	EU
	Transmitter frequencies [MHz]						
	40,66 to 40,7 433,05 to 434,79	868 to 870	868,6 to 869,7	34,995 to 35,225 40,665 to 40,695	863 to- 865	446,006 2 5 to 446,093 7 5	446,1 to 446,2
	Distance to source [m]						
A (controlled)	Case-by-case according to the equipment requirements						
1 0,3 V/m	2,1	16	3,6	7,2	2,3	16	16
2 1 V/m	0,96	5,0	1,1	1,9	0,7	5,0	5,0
3 3 V/m	0,66	1,7	0,37	0,98	0,23	1,7	1,7
4 10 V/m	0,45	0,5	0,098	0,66	0,063	0,48	0,48
5 30 V/m	0,32	0,16	0,046	0,47	0,04	0,14	0,14
X (harsh)	Case-by-case according to the situation						

NOTE SRD and PMR mean the short range devices and the private mobile radio, respectively. Radio microphones, wireless telemetries, radio control radio services, citizens band radio services, personal wireless communications, cordless phones, and other short range devices are categorized in the table. However, wireless telemetries and citizens band radio services are not treated here. Some frequencies of PMR and digital PMR allocate for cordless phones. The fields are also calculated from Formula (B.4) in Annex B.

The power values mentioned in Table 31 are a summary of all frequencies and the maximum allowed output power of the transmitter given as P_{PEP} (peak envelope power) of all three ITU regions. The output power used for the calculation of the distances in the table is P_{PEP} multiplied by the theoretical antenna gain of a half-wavelength dipol antenna (2,15 dB) and is given as P_{EIRP} (equivalent isotropically radiated power). Possible losses from cables, switches and mismatches are not considered to keep the model as simple as possible. The calculated field strength is only valid for the main beam of the antenna and is lower outside this beam.

The distances may vary in real situations because the typical antenna gain is different (up to 10 dB or more) and losses (e.g. from cables) have to be taken into account. These (mostly rotatable) high gain antennas are normally mounted on antenna towers 10 m to 30 m above ground or on a roof. In this case only in the direction of the main beam of the antenna the full field strength will occur. Even for slight deviations from the direction of maximum beam strength significant reductions of the antenna gain are observed.

Table 31 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Amateur radio bands above 30 MHz

Disturbance degree and corresponding field strength	Phenomena (sources)		
	Amateur radio station P = 1 500 W P_{EIRP} ≈ 2 500 W	Amateur radio station P = 1 500 W P_{EIRP} ≈ 2 500 W	Amateur radio station P = 1 500 W P_{EIRP} ≈ 2 500 W
	Transmitter frequencies [MHz]		
	50 to 54 144 to 148 219 to 220 420 to 450 902 to 928	1 240 to 1 300 2 300 to 2 450 3 300 to 3 500 5 650 to 5 925	10 000 to 10 500 24 000 to 24 250 47 000 to 47 200 75 500 to 81 500 122 250 to 123 000 134 000 to 141 000 241 000 to 250 000 >275 000
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 0,3 V/m	905	905	905
2 1 V/m	271	271	271
3 3 V/m	90,5	90,5	90,5
4 10 V/m	27,1	27,1	27,1
5 30 V/m	9,05	9,05	9,05
X (harsh)	Case-by-case according to the situation		

NOTE 1 The distances are derived assuming a power of 1 500 W and an antenna gain of 2,15 dBi of a half wavelength dipole antenna. Practical limitations restrict the antenna gain for the lower frequency bands and the amplifier power for the higher frequency bands.

NOTE 2 The above mentioned power and frequency bands are a summary of all three ITU regions. The power P is (if not otherwise mentioned) the allowed maximum output power of the amplifier. The power arriving at the antenna and radiated by it is P_{ANT} and is P reduced by the losses of the feeding cable. For easy calculation of E and d, the effective isotropic power P_{EIRP} is useful. Most antennas have a direction with maximum radiation, i.e. in that direction they have a significant antenna gain G_{ISO} compared to an isotropic radiator. E and d of this maximum radiation can be easily calculated by means of P_{EIRP}, which is obtained by multiplying P_{ANT} by the isotropic antenna gain G_{ISO}. d is the spatial distance from the antenna. A power P = 1 500 W fed into a dipole results in an isotropic effective radiated power of about P_{EIRP} ≈ 2 500 W.

In case of an amateur radio station at VHF, UHF, SHF and EHF many antenna types are possible. Typical resulting antenna gains G_{ISO} are between about 10 dBi and > 30 dBi. These (mostly rotatable) antennas are normally mounted on antenna towers 10 m to 30 m above ground or on a roof. In this case only in the direction of the main beam of the antenna the full field strength will occur. Even for slight deviations from the direction of maximum beam strength significant reductions of the antenna gain are observed.

The same values for P_{EIRP} and therefore for E and d in the beam direction for the amateur station in this example could also be obtained with P = 100 W, a feeding cable attenuation of 2 dB and a directional antenna with an isotropic antenna gain G_{ISO} of 16 dBi. However, with the same P_{EIRP} the disturbing probability of such an antenna is much lower than that of an omnidirectional antenna, because the beam width is limited in the horizontal and vertical plane.

Table 32 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Paging service base station

Disturbance degree and corresponding field strength	Phenomena (sources)				
	POCSAG P = 250 W_{ERP}	POCSAG P = 100 W_{ERP}	ERMES P =250 W_{ERP}	FLEX™, Re FLEX™ E =1 kW_{ERP}	POCSAG P = 100 W_{ERP}
	Countries				
	JP	EU	EU	US	UK
	Transmitter frequencies [MHz]				
	276,012 5 to 283,987 5	439 to 466	169	900	138, 153, and 466
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	370	230	370	740	230
2 1 V/m	111	70	111	222	70
3 3 V/m	37	23	37	74	23
4 10 V/m	11	7	11	22	7
5 30 V/m	3,7	2,3	3,7	7,4	2,3
6 100 V/m	1,1	0,69	1,1	2,2	,69
X (harsh)	Case-by-case according to the situation				
NOTE The absolute gain of each base station antenna is 2,15 dBi, if a half wavelength dipole antenna is used for the base station. The fields are calculated from Formula (B.4) in Annex B.					

Table 33 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Other RF items (1 of 6)

Disturbance degree and corresponding field strength	Phenomena (sources)				
	RTTT P= 8 W_{ERP}	Wideband data transmission systems and HIPERLANs P = 0,1 W_{ERP}	Wideband data transmission systems and HIPERLANs P = 0,2 W_{ERP}	Wideband data transmission systems and HIPERLANs P = 1 W_{ERP}	Non specific short range devices P = 0,025 W_{ERP}
	Transmitter frequencies [GHz]				
	5,795 to 5,815	2,400 to 2,483 5	5,150 to 5,350	5,470 to 5,725	2,400 to 2,483 5 5,725 to 5,875
	Distance to source [m]				
A (controlled)	Case-by-case according to the equipment requirements				
1 0,3 V/m	66	58	83	183	3,7
2 1 V/m	20	17	24	55	1,1
3 3 V/m	6,6	5,8	8,2	18	0,74
4 10 V/m	2	1,7	2,5	5,5	0,22
5 30 V/m	0,66	0,58	0,82	1,8	0,074
X (harsh)	Case-by-case according to the situation				
NOTE The absolute gain of wideband data transmission systems/HIPERLANs is assumed to be 20 dBi maximum (for fixed wireless access service). The absolute antenna gain of RTTT and non specific short range devices is assumed to be 2,15 dBi.					

Table 34 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Other RF items (2 of 6)

Disturbance degree and corresponding field strength	**Phenomena (sources)**		
	Wideband data transmission systems and HIPERLANs Terminal P = 0,1 W_{ERP}	Wideband data transmission systems and HIPERLANs Terminal P = 0,2 W_{ERP}	Wideband data transmission systems and HIPERLANs Terminal P = 1 W_{ERP}
	Transmitter frequencies [GHz]		
	2,400 to 2,483 5	5,150 to 5,350	5,470 to 5,725
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 0,3 V/m	7,4	10	23
2 1 V/m	2,2	3	7
3 3 V/m	0,74	1	2,3
4 10 V/m	0,22	0,3	0,7
5 30 V/m	0,074	0,1	0,23
X (harsh)	Case-by-case according to the situation		
NOTE The absolute gain of wideband data transmission systems/HIPERLANs is assumed to be 2,14 dBi (for terminals).			

Table 35 – Disturbance degrees, levels (in V/m, rms) and distance to source – Other RF items (3 of 6)

Disturbance degree and corresponding field strength	**Phenomena (sources)**	
	Fixed microwave services P_{EIRP} = 55 dBW (316 kW)	Vehicle-mounted field disturbance sensors (vehicle radar system) P = 60 μW/cm^2 at 3 m
	Transmitter frequencies [GHz]	
	92 to 95	46,7 to 46,9 76 to 77
	Distance to source [m]	
A (controlled)	Case-by-case according to the equipment requirements	
1 0,3 V/m	10 200	135
2 1 V/m	3 080	45
3 3 V/m	1 020	15
4 10 V/m	308	4,5
5 30 V/m	102	1,5
X (harsh)	Case-by-case according to the situation	

Table 36 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Other RF items (4 of 6)

Disturbance degree and corresponding field strength	Phenomena (sources)	
	Non specific short range devices (see ERC Recommendation 70-03) [a] P = 100 mW_{EIRP}	Road transport and traffic telematics (RTTT) [b]
	Transmitter frequencies [GHz]	
	61,0 to 61,5 122 to 123 244 to 246	63 to 64
	Distance to source [m]	
A (controlled)	Case-by-case according to the equipment requirements	
1 0,3 V/m	5,75	x
2 1 V/m	1,7	x
3 3 V/m	0,57	x
4 10 V/m	0,17	x
5 30 V/m	0,06	x
X (harsh)	Case-by-case according to the situation	

[a] No power limitations, it has to be assessed case-by-case.

[b] No power limits currently specified; however, this might change in the future.

Table 37 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Other RF items (5 of 6)

Disturbance degree and corresponding field strength	Phenomena (sources)	
	TETRA system P = 8 W_{ERP}	UWB P = 0,11 mW_{EIRP} [b]
	Transmitter frequencies	
	380 MHz to 921 MHz [a]	3,1 GHz to 10,6 GHz, 22 GHz to 29 GHz
	Distance to source [m]	
A (controlled)	Case-by-case according to the equipment requirements	
1 0,3 V/m	66	0,25
2 1 V/m	20	0,074
3 3 V/m	6,6	0,025
4 10 V/m	2	0,007 4
5 30 V/m	0,66	0,002 5
X (harsh)	Case-by-case according to the situation	

[a] See Table B.3.

[b] In ITU-R recommendation SM 1756, the spectrum mask is specified by EIRP as -41,3 dBm/MHz. If the spectrum is assumed to be flat in the occupied bandwidth (in a case of multiband OFDM UWB, the bandwidth of a channel group is 1 584 MHz), the total power is evaluated as -9,3 dBm = 0,11 mW. An antenna gain of 0 dBi is assumed in this case.

Table 38 – Disturbance degrees, levels (in V/m, rms) and distance to source – Other RF items (6 of 6)

Disturbance degree and corresponding **field strength**	**Phenomena (sources)**		
	Road transport and traffic telematics (RTTT) P_{EIRP} = 55 dBm (PK) [a] P_{EIRP} = 50 dBm (AV) P_{EIRP} = 23,5 dBm (AV) [b]	Field disturbance sensors, incl. vehicle radar systems P = 500 mW_{PEP} [c]	Non specific equipment, indoor use only P = 500 mW_{PEP} [c]
	Transmitter frequencies [GHz]		
	76 to 77	57 to 64	92 to 95
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 0,3 V/m	324	129	129
2 1 V/m	97	38,5	38,5
3 3 V/m	32,4	12,9	12,9
4 10 V/m	9,7	3,85	3,85
5 30 V/m	3,24	1,29	1,29
X (harsh)	Case-by-case according to the situation		

a Calculation done with 55 dBm.

b Pulse radar only.

c Calculation done for 20 dBi antenna gain.

6.2.3.3 Radio frequency identification (RFID) systems

Radio frequency identification (RFID) is a contactless identification technology. It operates by generation and propagation of electromagnetic waves. The purpose of an RFID system is to enable data to be transmitted by a transponder, which is read by an RFID reader and processed according to the needs of a particular application. There are three main components of an RFID: an antenna, a transceiver and a transponder. The antenna enables communication between the transponder and the transceiver. RFID is extensively used in tracking and access applications and can work in ranges exceeding 30 m depending on the frequency and type of transponder used.

RFID systems can be classified in accordance with their frequency of operation, however the frequency of use of an RFID system is restricted to the industrial, scientific and medical (ISM) and short range devices (SRD) frequency bands. RFID systems operate by a variety of coupling methods but the most common methods are inductive coupling for low frequency (LF) RFID systems and backscatter coupling for ultra high frequency (UHF) and super high frequency (SHF) RFID systems. RFID systems can also be classified based on how the transponder is powered: passive RFID systems rely on the RF energy transferred from the transceiver to the transponder to power the transponder, whereas active RFID systems use an internal power source (usually a battery) within the transponder to continuously power the transponder and its RF communication circuitry. Table B.7 summarises the RFID technology.

Table 39 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – RFID and railway transponder systems

Disturbance degree and corresponding **field strength**	**Phenomena (sources)**						
	RFID [a] P = 1 W	RFID [b] P = 4 W	Railway transponder system P = 20 W	RFID [c] P = 10 mW_{ERP}	RFID [d] P = 1 W (antenna gain = 6 dBi)	RFID [e] P = 4 W_{EIRP}	RFID P = 4 W_{EIRP}
	Transmitter frequencies [MHz]						
	Below 0,135	13,56	27	433	860 to 960	2 450	5 875
	Distance to source [m]						
A (controlled)	Case-by-case according to the equipment requirements						
1 0,3 V/m	0,2	3,3	20	2,3	36	36,55	36,55
2 1 V/m	0,11	1,6	6	0,69	11	11	11
3 3 V/m	0,062	0,9	2,5	0,21	3,6	3,7	3,7
4 10 V/m	0,035	0,49	1,1	0,091	1,1	1,1	1,1
5 30 V/m	0,02	0,28	0,62	0,063	0,36	0,37	0,37
X (harsh)	Case-by-case according to the situation						

NOTE 1 There may be different frequencies used for services such as RFID in different countries. A corresponding evaluation of the field strengths to be expected can be done according to the Formulae (B.6) and (B.7) (for further information on the frequency bands used see www.ero.dk).

NOTE 2 The fields are calculated from Formula (B.6) in Annex B in the cases of 135 kHz and 13,56 MHz RFID, and railway transponder systems. The fields are calculated from Formula (B.4) in Annex B in the cases of the other systems. The loop current is given by the input power into the loop antenna of an RFID reader. When the impedance of the loop antenna is matched to that of the driver circuit of the RFID (usually Z_0 = 50 Ω), the loop current, I, is obtained as $I = (P/\ Z_0)0{,}5$. The values of the current are 0,14 A, 0,28 A, and 0,63 A in the case of 135 kHz and 13,56 MHz RFID, and railway transponder systems, respectively. The loop area, S, as shown in Annex B is assumed as 1 m^2.

[a] See ISO/IEC 18000-2.

[b] See ISO/IEC 18000-3.

[c] See ISO/IEC 18000-7.

[d] See ISO/IEC 18000-6.

[e] See ISO/IEC 18000-4; the power level is specified by EIRP, an antenna gain of 0 dBi is assumed.

The disturbance degrees in near-field magnetic-fields are expressed in Table 40.

Table 40 – Disturbance degrees, levels (in µA/m, r.m.s.) and distance to source – RFID and railway transponder systems

Disturbance degree and corresponding **field strength**	**Phenomena (sources)**		
	RFID [a] P = 1 W_{ERP}	RFID [b] P = 4 W_{ERP}	Railway transponder system P = 20 W_{ERP}
	Transmitter frequencies [MHz]		
	Below 0,135	13,56	27
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 3 µA/m	16	600	5 300
2 10 µA/m	10	180	1 600
3 30 µA/m	7,2	60	530
4 100 µA/m	4,8	17	160
5 300 µA/m	3,3	5,2	53
6 1000 µA/m	2,2	2,7	16
X (harsh)	Case-by-case according to the situation		

NOTE The fields are calculated from Formula (B.7) in Annex B. The loop current is defined by the input power into the loop antenna of an RFID reader. When the impedance of the loop antenna is matched to that of the driver circuit of the RFID (usually Z_0 = 50 Ω), the loop current I, is obtained as $I = (P/ Z_0)/2$. The values of the current are 0,14 A, 0,28 A and 0,63 A in the case of 135 kHz, 13,56 MHz and 27 MHz, respectively. The loop area S, as shown in Annex B, is assumed as 1 m^2.

[a] See ISO/IEC 18000-2.

[b] See ISO/IEC 18000-3.

6.2.3.4 Magnetic fields from 9 kHz to 150 kHz

Magnetic fields are also generated by sources operating at frequencies other than power frequencies (or harmonics of power frequencies). The most typical application of such intentionally generated magnetic fields is in short range communication systems. Other applications include induction heating.

For intentional radiators, the items tend to be short range communication systems of unidirectional and bidirectional capability. In general, these systems are characterised by a transponder system and a base station both of which comprise an inductive loop. Depending on the system and application, the transponder could be passive, a term used to describe the fact that the transponder does not contain a power source but obtains its operating power via magnetic coupling between the base station and the transponder, or active where the transponder has an integrated power source.

Short range communication systems are used extensively for supply chain management applications as well as in animal husbandry, retail security (i.e. RFID applications, see 6.2.3.3) and railway signalling systems to name a few. Typical frequencies of operation are 29 kHz, 30 kHz, 36 kHz, 43 kHz, 56 kHz, 125 kHz and 134,2 kHz.

For these items the radiated magnetic field is a function of the loop area and EIRP. Typical values of magnetic fields from such systems are given in Table 40.

6.2.4 Radiated pulsed disturbances

Pulsed (transient) radiated disturbances of interest are those which might, despite a short duration, have an influence on the item because of their important instantaneous rate of rise.

In fact, real pulses exhibit very complicated waveforms, which sometimes are only partially known because of the limited bandwidth of measurement tools.

The values encountered in practice strongly depend on the distance between victim and source (see Annex B for more information). Because the phenomenon involves coupling of a field into the equipment circuits, the derivative, or rate of rise of the pulse, and the front duration are the significant attributes of the phenomenon. Hence no specific distances can be given in Table 41.

For the purpose of this document, pulsed radiated disturbances are the radiated disturbances which do not last for more than 200 ms, and which do not change polarity more than 10 times for their duration (further information is given in Annex D).

Table 41 – Disturbance degrees, levels (in rate of rise) and distance to source – Radiated pulsed disturbances

Disturbance degree and corresponding rate of rise	**Phenomena (sources)**			
	Open field Lightning strike to ground [a, b]	Gas-insulated substations Disconnect switch [c]	Air-insulated substations Disconnect switch [c]	Below overhead lines conducting lightning surges and switching operations [c]
	Rise time [ns]			
	100 to 500	10	100	1 000
	Distance to source [m]			
A (controlled)	Case-by-case according to the equipment requirements			
1 30 V m^{-1} ns^{-1}	*d*	*d*	*d*	*d*
2 100 V m^{-1} ns^{-1}	*d*	*d*	*d*	*d*
3 300 V m^{-1} ns^{-1}	*d*	*d*	*d*	*d*
4 1000 V m^{-1} ns^{-1}	*d*	*d*	*d*	*d*
5 3000 V m^{-1} ns^{-1}	*d*	*d*	*d*	*d*
X (harsh)	Case-by-case according to the situation			

NOTE These phenomena involve the coupling of a field into the equipment circuits. Therefore the derivative, or rate of rise of the pulse, and the front duration are the significant attributes of the phenomenon. For this reason, no specific disturbance distances can be given here.

[a] At a distance d greater than about 30 m.

[b] The amplitude of the disturbance degree depends on the distance and the steepness of the lightning strike. The shielding offered by metallic structures, buildings and terrain profile can be expected to be effective in reducing the amplitude.

[c] The amplitude of the disturbance is very much dependent on the distance from the source. It also depends on the amplitude of the source phenomenon, which is roughly proportional to the operating voltage of the system. This fact is generally compensated by the need to keep, for insulation requirements, greater distances from sources operating at higher voltages. The latter situation does not apply to gas-insulated substations.

Table 42 – Disturbance degrees, levels (in V/m, Pk) and distance to source – RADAR systems

Disturbance degree and corresponding field strength	Phenomena (sources)		
	Ground traffic control (police) 500 mW ($EIRP_{Pk}$)	Ground traffic control (airport) 30 kW ($EIRP_{Pk}$)	Car-mounted RADAR (adaptive cruise control) 316 W ($EIRP_{Pk}$) [a]
	Transmitter frequency [GHz]		
	24,125	9,1	77
	Distance to source [m]		
A (controlled)	Case-by-case according to the equipment requirements		
1 0,3 V/m	40,7	3 160	324
2 1 V/m	12,2	948	97,0
3 3 V/m	4,07	316	32,4
4 10 V/m	1,22	94,8	9,70
5 30 V/m	0,41	31,6	3,24
X (harsh)	Case-by-case according to the situation		

NOTE The RADAR systems in this table are examples of systems which can be found in traffic areas or airports. In some situations higher levels or other frequencies can occur.

[a] The power level (of 316 W $EIRP_{Pk}$) used for the calculation is the maximum level allowed according to EN 301 091 V1.1.1 for this type of RADAR systems. The power level of actual systems in use is much lower (approx. 10 W $EIRP_{Pk}$).

7 Electrostatic discharge

7.1 General

Electrostatic discharge (ESD) occurs as a result of a charged person or object approaching another person or object. The ESD receptor is first subjected to the electric field associated with the charge, then, when dielectric breakdown occurs, there is a discharge with transient current of a complex nature that gives rise to a transient electromagnetic field. The ESD phenomenon is strongly dependent on ambient humidity, temperature, nature of surrounding dielectrics, etc.

7.2 ESD currents

Table 43 shows the values of the rate of current rise associated with the air discharge, the significant attribute in producing disturbing fields. This table also shows the charge voltage before discharge, a significant attribute in the potential for energy exchange, as well as current amplitude.

There is no strict correlation between the values of charge voltage and the rates of rise of current given in Table 43, because other characteristics of the ESD event can influence the outcome.

Table 43 – Disturbance degrees and levels for pulsed disturbances (rate of rise) caused by ESD

Disturbance degrees	Phenomena (sources)			
	Slow ESD		Fast ESD	
	Rise time: 5 ns Duration: 15 ns Rate of occurrence: Single Frequency of occurrence: [a] Source: 100 Ω to 500 Ω [b] 100 pF to 500 pF [c]		Rise time: 0,3 ns Duration: 2 ns Rate of occurrence: Single Frequency of occurrence: [a] Source: 100 Ω to 500 Ω [b] 100 pF to 500 pF [c]	
	Significant attribute			
	(A/ns)	(kV)	(A/ns)	(kV)
A (controlled)	Case-by-case according to the equipment requirements			
1	-	-	-	<1
2	25	-	25	2
3	40	-	40	4
4	80	8	80	8
5	100	15	-	-
6	-	30	-	-
X (harsh)	Case-by-case according to situation			

[a] Depends on the number of persons in the area.

[b] Depends on the source: hand tool, bare hand, furniture.

[c] Depends on an individual's isolation or size of furniture at the instance of the discharging process.

7.3 Fields produced by ESD currents

Table 44 shows the values of transient electric and magnetic fields gradients external to the receptor, measured at a distance of 0,1 m from the discharge. See Annex C for further information.

Table 44 – Disturbance degrees and levels for radiated field gradients caused by ESD

Disturbance degrees	Level of radiated field gradients	
	$V\ m^{-1}\ ns^{-1}$	$A\ m^{-1}\ ns^{-1}$
A (controlled)	Case-by-case according to the equipment requirements	
1	2 000	5
2	4 000	10
3	8 000	20
4	16 000	40
X (harsh)	Case-by-case according to the situation	

8 Classification of environments

8.1 General

In general, the electromagnetic environment at a given location is determined by the combination of the naturally-occurring and man-made electromagnetic phenomena present and the disturbance level at which each phenomenon occurs.

The electromagnetic environment is not the same at all locations, since the electromagnetic phenomena described in Clauses 5, 6 and 7 do not all occur at every location, nor do those phenomena present always occur with the same disturbance level. Since the majority of the phenomena described in Clauses 5, 6 and 7 are man-made, the existence of a given phenomenon and its associated disturbance level at a given location generally depends upon factors that include: the types and numbers of electrical and electronic equipment (including radio transmitting equipment) operated at and nearby the location.

For the purpose of simplicity, it is useful to describe a minimal set of location classes that contain the phenomena and associated disturbance levels that are typical of a large number of locations. This document defines a minimal set of archetypical location classes. The background to this selection is presented in 8.2, and 8.3 to 8.5 describe each archetype location class.

8.2 Location classes

Patterns of land use are noted to vary significantly between different regions of the world. The observed differences are due largely to the combination of geographical, historical and cultural differences towards the concept of land use regulation and its enforcement through local legal frameworks.

One extreme pattern of land use is observed within those population centres that have developed with the concept of land use regulation (and its associated enforcement through local legal frameworks) adopted from the very outset. In this instance, the population centres are divided into a number of functionally distinct, clearly delineated, separate sections (often referred to as 'zones'). A change in land use occurs relatively infrequently, due to the time taken to engage with the relevant process embodied within the local legal framework.

The opposite extreme in the pattern of land use is observed within population centres that have developed without any application of the concept of land use regulation. In this instance, there is no division of the centre into functionally distinct, clearly delineated, separate sections; rather the centres are characterised by a largely ad hoc land use, with many diverse functions being performed within the same area. In such a location, changes in land use occur relatively frequently, again in a largely ad hoc manner.

Many other patterns of land use are observed across the different regions of the world that fall somewhere between these two extremes.

Land use regulation controls the activities that may take place at a given location. For the purposes of this document, it therefore similarly controls the types of electrical and electronic equipment (including radio transmitting equipment) that are likely to be situated at a given location and in doing so influences the types and severity of the electromagnetic phenomena present in the electromagnetic environment at a given location.

Within this document, three archetypal land uses, location classes and hence electromagnetic environments are recognised, these being:

– residential;
– commercial/public;
– industrial.

In practice, the actual electromagnetic environment at a given location can be thought of as the weighted combination of the three archetypes. This concept is displayed on Figure 7.

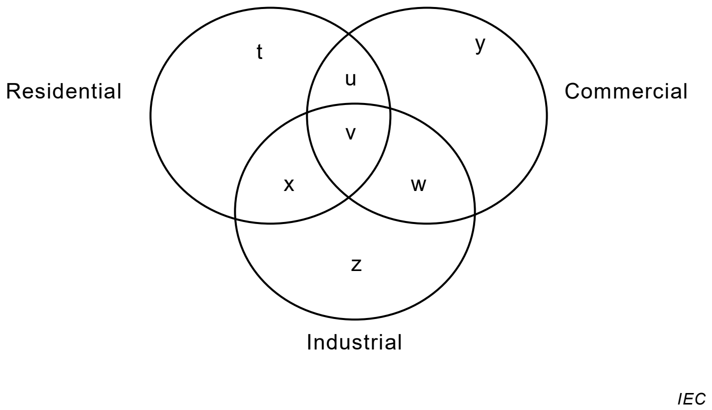


Figure 7 – Concept of location classes

Note that Figure 7 can be interpreted in two ways:

1) As a spatial diagram, indicating the environments created due to the specification and delineation of separate areas as residential, commercial and industrial.

   Any location in the centres of these separate areas will therefore experience the archetypical electromagnetic environments (areas t, y and z on Figure 7). However, locations at the boundary or boundaries between these separated areas (areas u, v, w and x on Figure 7) will experience an electromagnetic environment that is a blend of the archetypical environments, containing phenomena from the adjacent archetypes.

2) As a functional diagram, demonstrating how changes in the activities performed in a designated area (i.e. the area 'function') can lead to the location's environment deviating from the archetype through the introduction of electrical or electronic equipment (and hence of phenomena or a severity of phenomena) not associated with the archetype. Examples include:

   – The location and operation of a single/small number of ISM items within a residential area (e.g. a community health centre located within a residential area). In this instance the residential electromagnetic archetype is perturbed by the electromagnetic phenomena associated with the operation of ISM equipment. This gives rise to area x of Figure 7.

   – The location and operation of a single item of industrial machinery within a commercial area to provide a specific service (e.g. a car wash located near or within a public retail area). In this instance, the commercial electromagnetic environment is perturbed by the electromagnetic phenomena associated with the operation of the industrial machinery. This gives rise to area w of Figure 7.

   – The entirely ad hoc location of electrical and electronic equipment at a given area with undesignated land use (e.g. the Developing World scenario described earlier). In this instance, the electromagnetic environment will contain phenomena and severity levels associated with all three archetypes. This gives rise to area v of Figure 7.

   – The location and operation of telecommunications, office and IT equipment means that low levels of administrative/service industry activity may be performed within domestic premises (i.e. home offices) rather than in commercial premises (i.e. small offices). This gives rise to area u of Figure 7.

It is noted that area z of Figure 7 can also be applied to roads and railways: by their very nature, roads and railways pass either by or through all areas of designated land use (often being the boundary between the separated areas of designated land use) and hence experience phenomena and a severity of phenomena from each archetype. The range and severity of phenomena will vary from location to location, depending upon the adjacent land use. These phenomena are in addition to any intrinsic phenomena associated with the road and railways: for example, the railways will have phenomena associated with signalling systems and the use of large electrical traction systems.

It is on this basis that 8.3 to 8.5 describe the essential properties of the three archetypes.

8.3 Residential location class

8.3.1 Description of residential locations

In accordance with Figure 7, the residential location exists in an area of land designated for the construction of domestic dwellings. The function of a domestic dwelling is to provide a place for one or more people to live.

The domestic dwelling delivers a number of functions that may employ electrical or electronic equipment. These functions include:

– the provision of either heating or cooling (depending upon the prevailing environment);
– the provision of light;
– the provision of hot water for the purposes of maintaining personal hygiene.

The domestic dwelling also supports a number of activities that may employ electrical or electronic equipment. Such activities include:

- the storage and preparation of food;
- the cleaning and drying of clothing;
- the operation of IT equipment;
- the consumption of broadcast or streamed entertainment services.

A dwelling can be a single, separate building (as in a detached house) or a separate section of a larger building (as in an apartment in an apartment block).

Subclause 8.3 considers the electromagnetic environment within a domestic dwelling. The approach taken is to treat the individual dwelling as an item of electrical or electronic equipment. This allows the dwelling to have the standard IEC ports.

8.3.2 Equipment typical to the residential location

Any equipment within the residential location is connected to the internal low-voltage power supply network via either transformer-based or switched mode power supplies.

The residential location is characterised by the ad hoc location of electrical and electronic equipment performed by the residents. Equipment items can therefore be placed very near to or in contact with one another in certain high density locations. These locations include:

– the home office desk, with PC located on/below the desk; VDU, speakers, printer, wireless keyboard and wireless mouse located on the desktop; portable telephone handset and/or cellular telephone handset located on the desktop, near to or in physical contact with one of the items;
– the 'adolescent's bedroom', that may contain the above described home office desk in addition to a TV set with DVD/VCR and games console.

High density locations typically access the internal low-voltage power supply network via a single outlet socket that is fitted with a distribution board/power strip.

A non-exhaustive list of the types of equipment present and operated within the residential location is presented in Table 45. The equipment has been categorised according to function.

Table 45 – Examples of equipment present in the residential location class

Equipment Function	Examples
Food preparation/storage	Storage: Refrigeration and/or freezing Preparation: Microwave oven, electric oven, electric hob, electric induction heating, gas oven, gas hob with electrostatic ignition Preparation: Toaster, water kettle, rice cooker, steamer, bread-maker, ice-cream maker, waffle iron, sandwich toaster, food processor, steamer, deep fat fryer
Environmental	Lighting: Fluorescent lighting, dimmer switches, LV transformers – halogen lamps Heating: Central heating system and electronic controller
Cleaning	Washing machine, dryer (separate or integrated), vacuum cleaner, floor polisher, dishwasher
HVAC and sanitation	Power shower, electronic toilet, stair lift, tanning booth, electric blanket, medical equipment
Entertainment	TV broadcast receiver (terrestrial – analogue + digital) Radio broadcast receiver (terrestrial – analogue + digital) VCR/DVD/personal or digital video recorder (PVR or DVR) Associated equipment – surround sound speakers & amplifiers Hi Fi (networked and non-networked) Games consoles (networked and non-networked) Electronic toys/cybertoys Remote controlled toys
IT	PC Wireless mouse/keyboards Home network equipment Home gateway, wireline/wireless items, PLT
Security	Cameras/camera networks Wireless gate/garage locks

8.3.3 Boundaries relevant for equipment operated at residential locations

The domestic dwelling has the following separate wireline infrastructure:

– low-voltage power supply distribution network;
– telephony extension wiring;
– coaxial distribution network.

Hence conducted environments are required for each infrastructure.

Some dwellings are supplied by their own generator.

The domestic dwelling can possess the following internal infrastructure:

- low-voltage power supply distribution network;
- telephony extension wiring;
- coaxial distribution network;
- LAN cabling;
- water distribution network;

- room lighting units;
- heating/ventilation/air-conditioning units.

Internal infrastructure may be installed either during the construction of the dwelling or subsequently during a refit/remodelling exercise.

The enclosure port of the dwelling is therefore the dwelling boundary. When the dwelling consists of a single, separate building (as in a detached house) the enclosure port is the outer walls of the building. When the dwelling is a separate section of a larger building (as in an apartment in an apartment block), the enclosure port is the boundary (walls, ceiling and floor) to the dwelling.

8.3.4 Interfaces and ports to residential locations

The domestic dwelling can possess a number of external ports that connect internal infrastructure with external infrastructure as listed in the following antenna ports.

Reception antennas:

- internal coaxial distribution network that is connected to an external VHF broadcast radio reception antenna;
- internal coaxial distribution network that is connected to an external UHF terrestrial broadcast TV reception antenna;
- internal coaxial distribution network that is connected to an external coaxial distribution network and ultimately (an) external CATV broadcast reception antenna(s);
- internal coaxial distribution network that is connected to an external SHF satellite broadcast TV reception antenna;
- internal coaxial distribution network that is connected to an external xHF broadcast radio reception antenna.

Broadcast antennas:

- internal coaxial distribution network that is connected to an external licensed amateur radio antenna;
- internal coaxial distribution network that is connected to an external licensed citizen’s band (CB) antenna;
- internal coaxial distribution network that is connected to an external satellite-based internet access.

Power ports:

- internal low-voltage power supply distribution wiring that is connected to an external low-voltage AC power distribution network.

Signal ports:

- internal telephony extension wiring that is connected to an external wireline telecommunications network;
- internal coaxial distribution network that is connected to an external cable TV distribution network.

8.3.5 Attributes of residential locations

In addition to the more or less general characterization of residential locations attributes can be used to conclude more quantitatively on the compatibility levels present at a residential location. Table 46 gives a list of attributes applicable to the residential location class.

Table 46 – Attributes of the residential location class

Ports	Attributes	General
	External environment [a]	
Enclosure	Amateur radio further than 100 m [b]	X
	CB radio further than 20 m [b]	X
	Broadcast transmitter operating below 1,6 MHz further than 5 km [b]	X
	FM and TV transmitters further than 1 km [b]	X
	Cellular communication systems with remote base station further than 200 m (hand-held transceivers, e.g. GSM, WiMAX etc.) [b]	X
	Paging systems, base stations, further than 1 km [b]	X
	Aviation RADAR further than 5 km [b]	X
AC power	Feeding MV- or HV-line further than 20 m [b]	X
Signal	Telecommunication line [c]	X
	Cable TV [d]	X
	Internal environment [e]	
Enclosure	Cellular communication systems with external base station (hand-held transceivers, e.g. GSM, etc.)[f]	X
	Portable communication systems with internal base-station (hand-held transceivers, mobile phones i.e. CT, CT2, DECT, Bluetooth, Wi-Fi etc) [g]	X
	High concentration of multimedia and household equipment	X
	Presence of microwave oven up to 1,5 kW	X
	Presence of medical equipment (Group 2 according to CISPR 11) further than 20 m [b]	X
	Proximity to MV/LV substations further than 20 m [b]	X
	Proximity to arc welders (mobile) further than 20 m [b]	X
	Proximity to HV substations further than 100 m [b]	X
AC power	AC cabling LV	X
	High concentration of switched mode power supplies	X
	Existence of PLT equipment	X
Signal	Lines < 30 m [h]	X
	Lightning exposure	X

a	This portion of the table presents contributors to the electromagnetic environment within a location class that are located outside the location.
b	If the stated separation is fulfilled, the radiated field strength will not exceed the compatibility level given in Table A.1, otherwise the compatibility level needs to be adjusted.
c	This assumes a UTP connection from the PSTN.
d	This assumes a coaxial cable entering the location.
e	This portion of the table presents contributors to the electromagnetic environment within a location class that are located inside the location.
f	This deals with the radiated signal from the handheld transceivers located within the location class.
g	This deals with the radiated signal from both: the handheld transceivers and the base stations located within the location class.
h	This includes: Ethernet, security systems.

8.4 Commercial/public location class

8.4.1 Description of commercial/public locations

Commercial/public location is defined as the environment in areas of the centre of a city, offices, public transport systems (road/train/underground), and modern business centres containing a concentration of office automation equipment (PCs, fax machines, photocopiers, telephones, etc.). The following areas correspond to this environment:

– retail outlets, for example shops, supermarkets;
– business premises, for example offices, banks, data centres (server farms);
– area of public entertainment, for example cinemas, public bars, dance halls;
– places of worship (e.g. temples, churches, mosques, synagogues);
– outdoor locations, for example petrol stations, car parks, amusement and sports centres.

8.4.2 Equipment and interference sources existent in commercial/public locations

Commercial/public locations are characterised by a high density of varying items of equipment installed and brought in by the public. Generally, the items of equipment provide a service for many users and can be operated simultaneously, and some of these might act as an adverse interference source. The electromagnetic environment in commercial/public locations is not constant but varies as a function of time depending on the functional use of the installation. A non-exhaustive list of equipment typically operated in a commercial/public location is given as follows:

– information technology equipment: a variety of fixed and mobile information technology equipment including but not limited to: mobile communication items, video information display systems, public address systems, audio frequency inductive loops, general IT equipment, POS terminals, audio frequency information systems (i.e. help points);
– transportation equipment: trams, buses, cars;
– lifts and escalators;
– power equipment: low and medium-voltage power equipment, power generators, UPS.

8.4.3 Boundaries relevant for equipment operated at commercial/public locations

There are several types of boundaries that should be considered for equipment used in commercial locations.

Boundaries of the commercial/public location with respect to the external environment:

– separation by spatial conditions such as fences, walls, or partitions;
– separation by electrical conditions by the substations that connect the commercial/public network to the other network;

– separation by organizational conditions that control access to the location of the installation.

The disturbances at those boundaries make up one part of the total electromagnetic environment to which an item of equipment is exposed at a commercial/public location.

The other part of the resultant electromagnetic environment is made up by the items of equipment in the location itself. The operation of those items of equipment causes electromagnetic disturbances forming a total disturbance level in the installation. The levels of disturbances as well as their characteristics might be affected by the placement of equipment and its installation conditions.

Boundaries of the commercial/public location with respect to the internal environment are as follows:

- separation by different power supplies;
- deliberate spatial separation of items of equipment;
- deliberate spatial separation of connection lines.

8.4.4 Interfaces and ports to commercial/public locations

At commercial/public location boundaries there exists interfaces/ports through which electromagnetic phenomena may propagate. In case of an enclosure port such propagation consists of radiated electromagnetic fields whereas in the case of an AC port the propagation consists of electromagnetic conducted disturbances.

Commercial/public locations share boundaries with other such locations as well as with residential and industrial locations. The interfaces shared with these external environments are:

– enclosure
– AC port
– DC port
– signal port (including telecommunication port)

There are also interfaces with equipment installed within the same commercial/public location. Such interface ports include:

- enclosure
- AC port
- DC port
- signal port (including telecommunication port)
- earth port (including both, functional and safety earth port)

8.4.5 Attributes of commercial/public locations

In addition to the more or less general characterization of commercial/public locations, attributes can be used to conclude more quantitatively on the compatibility levels present at a commercial/public location. Table 47 gives a list of attributes applicable to the commercial/public location class. The description by means of attributes further allows to take into account specific aspects of various locations of the commercial/public location class. The following table gives a list of attributes applicable to

– commercial locations;
– general public locations (park, amusement facilities, public offices, etc);
– public hospitals, educational institutions (school, university, college, etc);

– public traffic areas, railway stations, and airports.

The difference in these locations of the commercial/public location class refers mostly to one or two electromagnetic phenomena only. Hence a specific commercial/public location can essentially be described by the attributes of the commercial/public general type with a modification referring to some specific electromagnetic phenomena which are more or less distinct in the specific commercial/public location.

Table 47 – Attributes of various types of the commercial/public location class

Ports	Attributes	Commercial	Public/General	Public/Hospital	Public/Traffic
	External environment [a]				
Enclosure	Amateur radio further than 20 m [b]	X	X	X	X
	CB radio further than 20 m [b]	X	X	X	
	CB radio between 5 and 20 m				X
	Broadcast transmitter operating below 1,6 MHz further than 5 km [b]	X	X	X	X
	FM and TV transmitters further than 1 km [b]	X	X	X	X
	Cellular communication systems with remote base station further than 200 m (hand-held transceivers, e.g. GSM, WiMAX etc.) [b]	X	X		
AC power	Feeding MV- or HV-line [b]			X	X
Signal	Telecommunication line [c]	X	X	X	X
	Internal environment [d]				
Enclosure	Paging systems [f]	X	X	X	X
	Portable communication systems (hand-held transmitters, mobile phones) [e, f]	X	X	X	X
	Limited/controlled use of portable communication systems [b]			X	X
	High concentration of ISM equipment (Group 1 according to CISPR 11) [b]			X	
	Proximity to low-power ISM equipment (Group 2 according to CISPR 11), typically less than 1 kW [b]	X	X	X	X
	Proximity to high-power ISM equipment (Group 2 according to CISPR 11), typically more than 1 kW [b]			X	
	Proximity to LV and MV substations closer than 20 m [b]			X	X
	Proximity to HV substations closer than 20 m [b]				X
	Proximity of medium-voltage and high-voltage lines closer than 20 m [b]		X	X	X
	Proximity to arc welders (mobile) [b]				X
	Proximity to arc welders closer than 20 m [b]				
AC power	AC cabling LV [b]	X	X	X	X
	AC cabling MV [b]			X	X
	AC bus bar systems [b]			X	X
	Large power drive systems (> 16 A per phase) [b]			X	X
	Switching of inductive or capacitive loads				X
	Possibility of high fault currents				X
	High inrush loads				X