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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

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FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interest 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. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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

3) They have the form of recommendations for international use published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.

4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard, for example “state of the art”.

Technical reports of types 1 and 2 are subject to review within three years of publication to decide whether they can be transformed into International Standards. Technical reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

IEC 1000-2-5, which is a technical report of type 2, has been prepared by sub-committee 77B: High-frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

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

Committee draft	Report on voting
77B(SEC)122	77B/142/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 is issued in the type 2 technical report series of publications (according to G.4.2.2 of part 1 of the IEC/ISO Directives) as a “prospective standard for provisional application” in the field of electromagnetic compatibility because there is an urgent requirement for guidance on how standards in this field should be used to meet an identified need.

This document is not to be regarded as an “International Standard”. It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the IEC Central Office.

A review of this type 2 technical report will be carried out not later than three years after its publication, with the options of either extension for a further three years or conversion to an International Standard or withdrawal.

Annexes A, B and C are for information only.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 2: Environment –
Section 5: Classification of electromagnetic environments
Basic EMC publication

1 General

1.1 *Scope and object*

This section of IEC 1000-2 is a technical report intended for guidance, not as a specification, for those who are in charge of writing immunity standards for an equipment or system. Its purpose is to classify electromagnetic environments and help improve the specification of the immunity requirements of an item containing electrical or electronic parts, and consequently obtain electromagnetic compatibility. It also gives basic guidance for the selection of immunity levels. The data are applicable to any equipment, subsystem or system making use of electromagnetic energy and operating in a specific location as defined by this report. The environment inside transportation equipment (vehicles, traction, ships, aircraft) is not described in this report, but their effect on the surrounding environment is included.

It should be noted that the immunity level requirements chosen for the items are not only inevitably bound to their environment, but also to the requirements of the applications (e.g. for reliability or safety purposes). That could lead to more stringent requirements than usual. These levels may also be established for more general purposes such as generic and product standards, taking into account statistical and economical aspects as well as common experiences in certain application fields.

1.2 *Normative reference*

The following normative document contains provisions which, through reference in this text, constitute provisions of this section of IEC 1000-2. At the time of publication, the edition indicated was valid. All normative documents are subject to revision and parties to agreements based on this section of IEC 1000-2 are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(161): 1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

1.3 *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 IEC 50(161) makes reference to “electromagnetic phenomena”. The term *disturbance degree* is used in this report for quantifying the phenomena contributing to the electromagnetic environment, independently

of any consideration of test levels. The term “severity level” will not be used in this report 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 4, 5 and 6 of this report 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.) will be 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 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.

The final classification of environments into location classes and corresponding compatibility levels is discussed in clause 7, with specific examples of location classes given in the tables of annex A. The attributes of these location classes are based on the significant electromagnetic characteristics of a location, rather than geographical or structural aspects. For instance, the term “factory” is insufficient to categorize the location: in a factory, different localized conditions such as a computer room, general office space, as well as the manufacturing floor, proper, will be found.

The locations 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 encountered circa 1990 with an acceptable probability factor. The disturbance degrees shown in annex A are offered as examples of compatibility levels for the guidance of product committees, not as normative permitted levels or immunity requirements. Those values are affected by uncertainties, and might not describe extreme environments.

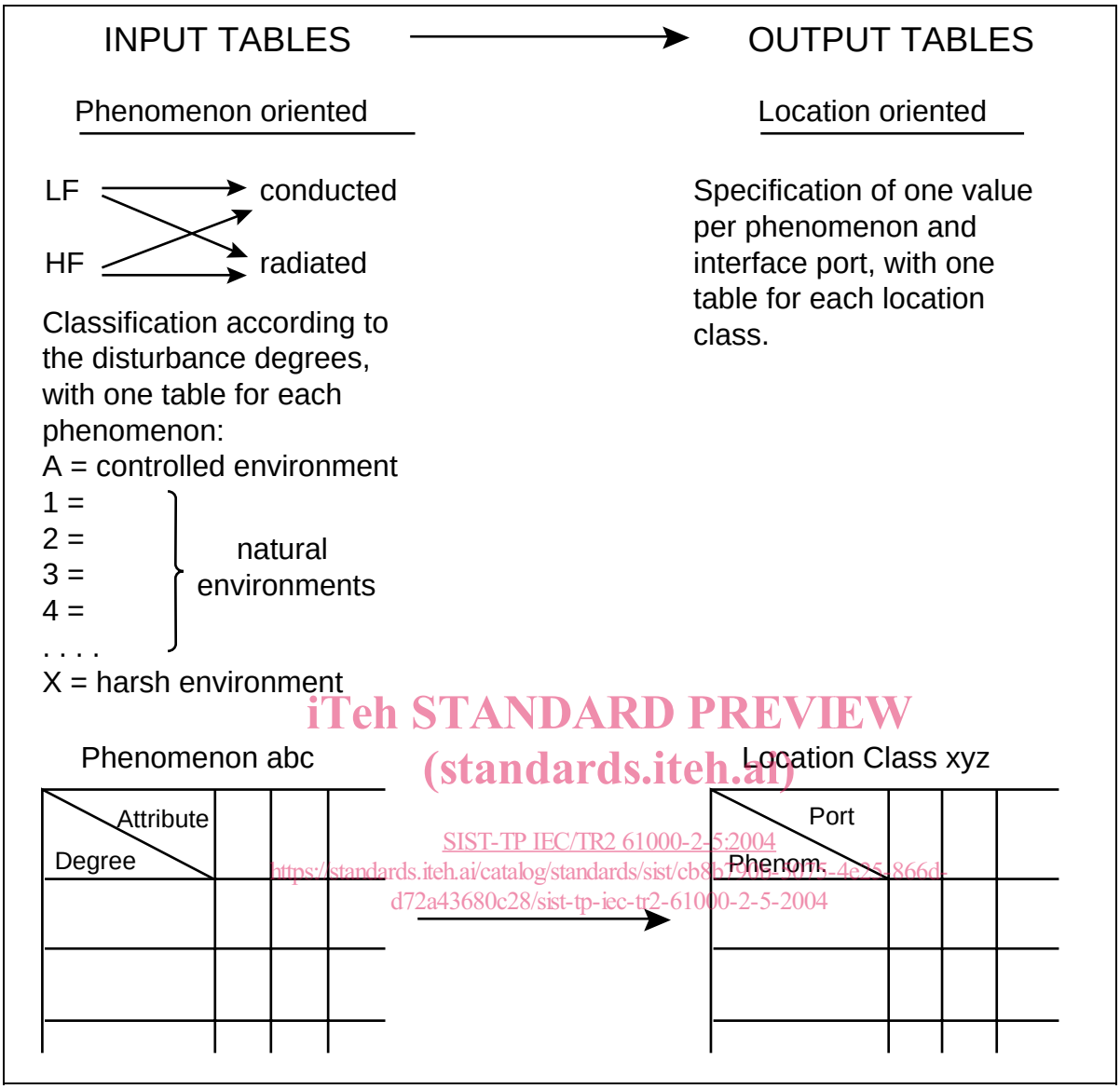

Figure 1 – Schematic of the two-step approach used for classification with phenomenon-oriented input tables and location-oriented output tables

2 Definitions

For definitions related to the general subject of electromagnetic compatibility, see IEC 50(161).

For the purpose of this section of IEC 1000-2, the following definitions apply.

Notes shown in normal characters are part of the IEC 50(161) definition. For the purpose of this report, notes shown in *italic characters* have been added to the definition given in IEC 50(161).

2.1 *Annotated definitions on electromagnetic compatibility*

2.1.1 **(electromagnetic) compatibility level:** Specified maximum electromagnetic disturbance level expected to be impressed on a device, equipment or system operated in particular conditions. [161-03-10]

NOTE – In practice the electromagnetic disturbance level is not an absolute maximum level but may be exceeded by a small probability.

2.1.2 **disturbance degree**: Specified, quantified intensity within a range of disturbance levels corresponding to a particular electromagnetic phenomenon encountered in the environment of interest.

2.1.3 **disturbance level**: Level of a given electromagnetic disturbance, measured in a specified way.

2.1.4 **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. [161-01-07, modified]

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

2.1.5 **(electromagnetic) environment**: Totality of electromagnetic phenomena existing at a given location. [161-01-01]

NOTES

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

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

2.1.6 **(electromagnetic) disturbance**: Any electromagnetic phenomenon which might degrade the performance of a device, equipment or system, or adversely affect living or inert matter. [161-01-05]

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

2.1.7 **(electromagnetic) susceptibility**: Inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance. [161-01-21]

NOTE – Susceptibility is a lack of immunity.

2.1.8 **immunity (to a disturbance)**: Ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance. [161-01-20]

2.1.9 **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. [161-03-14]

2.1.10 **location (EMC)**: Position or site marked by distinguishing electromagnetic features.

2.1.11 **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 (see annex A).

2.2 *Acronyms*

ASD adjustable speed drive (also variable speed drive)

CW continuous wave

ESD electrostatic discharge

EUT equipment under test

ISM industrial, scientific and medical equipment

ITE information technology equipment

MRI magnetic resonance imaging (also nuclear magnetic resonance).

3 User's guide for this report

3.1 *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 device 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 device.

3.2 *Environmental phenomena*

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

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

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”. A system 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. Large, long and high apply when the dimensions are, say, greater than 1. However, in the context of the present report, low means that the dominant part of the frequency spectrum of the disturbance is below 9 kHz and high if it is at frequencies (much) higher than 9 kHz.

Radiated disturbances occur in the medium surrounding the equipment, while conducted disturbances occur in various metallic media. The concept of ports, through which disturbances have an impact on the equipment, allows a distinction among these various media: 1) enclosure; 2) a.c. power mains; 3) d.c. power mains; 4) control/signal lines; 5) interface between systems 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.

3.3 *Simplification of the environmental 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 the types of phenomena. In this report, 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 are 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 report 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

Conducted low-frequency phenomena
– harmonics, interharmonics
– signalling voltages
– voltage fluctuations
– voltage dips and interruptions
– voltage unbalance
– power-frequency variations
– induced low-frequency voltages
– d.c. in a.c. networks
Radiated low-frequency phenomena
– magnetic fields
– electric fields
Conducted high-frequency phenomena
– induced CW voltages or currents
– unidirectional transients
– oscillatory transients
Radiated high-frequency phenomena
– magnetic fields
– electric fields
– electromagnetic fields
. continuous waves
. transients
Electrostatic discharge phenomena (ESD)
Nuclear electromagnetic pulse (NEMP) *
* Not considered in this report.

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 performance requirements for an equipment expected to be installed at various types of 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 report.

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 report 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 type of location. 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 must 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 type of location. 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 misoperation with unacceptable consequences).

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

a) selecting the appropriate location class from those defined in clause 7 and annex A;

b) selecting the required immunity in accordance with the principles stated in clause 8.

The purpose of this technical report 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 following tables are referred to well-known environmental conditions, such as low-frequency phenomena or, in other cases, only proposed as representative levels for classification.

4 Low-frequency electromagnetic phenomena

4.1 *Conducted low-frequency phenomena*

4.1.1 *Harmonics (≤3 kHz)*

Harmonic voltages are the result of harmonic currents from non-linear loads, flowing through the network impedances at the harmonic frequencies, and causing a corresponding voltage drop. The current and voltage contributions from various sources, such as several phase-controlled rectifiers, add vectorially so that the resulting voltage is less than or equal to the arithmetic sum of all contributions. A distinction can be made between two categories of sources:

– small sources in great number in the low-voltage networks, from a variety of electronic loads with rectifier input (household appliances, TV sets, personal computers, etc.);

– large individual sources on the LV, MV or HV networks, from industrial loads (such as adjustable speed drives), traction rectifiers, etc.