Railway applications — Electromagnetic compatibility —

Part 1: General

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British Standards

National foreword

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

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Foreword

This European Standard was prepared by Technical Committee TC 9X: Electrical and electronic applications for railways. The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50121-1 on 2006-07-01.

This European Standard supersedes EN 50121-1:2000.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2007-07-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2009-07-01

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and covers essential requirements of EC Directive 89/336/EEC. See Annex ZZ.

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Introduction

The railway EMC set of product-specific European Standards is intended, in the main, to permit compliance with the EMC Directive, but also to provide a means of prescribing compatibility between internal parts of the railway. It consists of five parts described at the end of this introduction.

The set of standards provides both a framework for managing the EMC for railways and also specifies the limits for the electromagnetic (EM) emission of the railway as a whole to the outside world and for the EM emission and immunity for equipment operating within the railway. The latter must be compatible with the emission limits set for the railway as a whole and also provides for establishing confidence in equipment being Fit For Purpose in the Railway environment. There are different stationary emission limits set for trams/trolleybuses and for metro/mainline railways. The frequency covered by the standards is in the range from d.c. to 400 GHz. No measurements need to be performed at frequencies where no requirement is specified. The limits for EMC phenomena are set so that the railway as a whole satisfies the Directive on electromagnetic compatibility with the outside world, and so that EMC is achieved between the various parts of the railway. Any specific problems in complying with the limits shall be addressed by the procedures given in the EMC Directive. Throughout the set of standards, the immunity levels are chosen to ensure a reasonable level of EMC with other apparatus within the local railway environment and with emissions which enter the railway from the outside world. Limits are also placed on EM emission by railways into the outside world.

The compatibility between railway emissions and their external environment is based upon emission limits from the railways being set by considering the results from measurements at the time that the EMC Directive became enforceable. Given that the general compatibility between railways and their environment was satisfactory at the time these measurements were made and subsequent experience of applying the limits has confirmed their acceptability, compliance with this Standard has been judged to give satisfactory compatibility. The immunity and emission levels do not of themselves guarantee that the railway will have satisfactory compliance with its neighbours. In exceptional circumstances, for instance near a "special location" (as defined in the EMC Directive) which has unusually high levels of EM interference, the railway system may require additional measures to be taken to ensure proper compatibility. Particular care should be taken when in proximity to equipment not covered by the EMC Directive such as radio transmission equipment, military or medical installations. Attention is particularly drawn to any magnetic imaging equipment in hospitals that may be near to urban transport. In all these cases, compatibility must be achieved with consultation and co-operation between the interested parties.

The immunity and emission levels do not of themselves guarantee that integration of the apparatus within the railway will necessarily be satisfactory. The standard cannot cover all the possible configurations of apparatus, but the test levels are sufficient to achieve satisfactory EMC in the majority of cases. In exceptional circumstances, for instance near a "special location" (as defined in the EMC Directive) which has unusually high levels of EM interference, the system may require additional measures to be taken to ensure proper operation. The resolution of this is a matter for discussion between the equipment supplier and the project manager, infrastructure controller or equivalent.

The railway apparatus is assembled into large systems and installations, such as trains and signalling control centres. Details are given in annex A. It is not, therefore, possible to establish immunity tests and limits for these large assemblies. The immunity levels for the apparatus will normally ensure reliable operation, but it is necessary to prepare an EMC management plan to deal with complex situations or to deal with specific circumstances. For example, the passage of the railway line close to a high power radio transmitter which produces abnormally high field strengths. Special conditions may have to be applied for railway equipment which has to work near such a transmitter and these will be accepted as National Conditions for the specification.

The series of Standards EN 50121, Railway applications - Electromagnetic compatibility, contains the following parts:

Part 1: General

This part gives a description of the electromagnetic behaviour of a railway; it specifies the performance criteria for the whole set. A management process to achieve EMC at the interface between the railway infrastructure and trains is referenced.

Part 2: Emission of the whole railway system to the outside world

This part sets the emission limits from the railway to the outside world at radio frequencies. It defines the applied test methods and gives information on typical field strength values at traction and radio frequency (cartography).

Part 3-1: Rolling stock - Train and complete vehicle

This part specifies the emission and immunity requirements for all types of rolling stock. It covers traction stock and trainsets, as well as independent hauled stock.

The scope of this part of the Standard ends at the interface of the stock with its respective energy inputs and outputs.

Part 3-2: Rolling stock - Apparatus

This part applies to emission and immunity aspects of EMC for electrical and electronic apparatus intended for use on railway rolling stock. It is also used as a means of dealing with the impracticality of immunity testing a complete vehicle.

Part 4: Emission and immunity of the signalling and telecommunications apparatus

This part specifies limits for electromagnetic emission and immunity for signalling and telecommunications apparatus installed within a Railway.

Part 5: Emission and immunity of fixed power supply installations and apparatus

This part applies to emission and immunity aspects of EMC for electrical and electronic apparatus and components intended for use in railway fixed installations associated with power supply.

EN 50121-1 and EN 50121-2 are product family standards which take precedence over generic standards.

EN 50121-3-1, EN 50121-3-2, EN 50121-4, and EN 50121-5 are product standards.

1 Scope

1.1 This Part 1 of the European standards series EN 50121 outlines the structure and the content of the whole set. This part alone is not sufficient to give presumption of conformity to the essential requirements of the EMC-Directive and must be used in conjunction with other parts of this standard.

Annex A describes the characteristics of the railway system which affect electromagnetic compatibility (EMC) behaviour.

Phenomena excluded from the set are Nuclear EM pulse, abnormal operating conditions and the induction effects of direct lightning strike.

Emission limits at the railway boundary do not apply to intentional transmitters within the railway boundaries.

Safety considerations are not covered by this set of standards.

The biological effects of non-ionising radiation as well as apparatus for medical assistance, such as pacemakers, are not considered here.

1.2 This European Standard is supplemented by the following specific standards:

EN 50121-2	Railway applications - Electromagnetic compatibility Part 2: Emission of the whole railway system to the outside world
EN 50121-3-1	Railway applications - Electromagnetic compatibility Part 3-1: Rolling stock - Train and complete vehicle
EN 50121-3-2	Railway applications - Electromagnetic compatibility Part 3-2: Rolling stock - Apparatus
EN 50121-4	Railway applications - Electromagnetic compatibility Part 4: Emission and immunity of the signalling and telecommunications apparatus
EN 50121-5	Railway applications - Electromagnetic compatibility Part 5: Emission and immunity of fixed power supply installations and apparatus

2 Normative references

The following referenced documents are indispensable for the application 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.

EN 50238	Railway applications – Compatibility between rolling stock and train detection systems
EN 61000-6-2	Electromagnetic compatibility (EMC) Part 6-2: Generic standards - Immunity for industrial environments (IEC 61000-6-2)
IEC 60050-161	International Electrotechnical Vocabulary (IEV) Chapter 161: Electromagnetic compatibility (EMC)

3 Definitions

For the purpose of this European Standard, definitions related to EMC and to relevant phenomena may be found in IEC 60050-161.

Other parts of this European Standard may contain specific definitions.

4 Performance criteria

NOTE This clause is based on EN 61000-6-2.

The variety and the diversity of the apparatus within the scope of this set of standards makes it difficult to define precise criteria for the evaluation of the immunity test results.

If, as a result of the application of the tests defined in this set of standards, the apparatus becomes dangerous or unsafe, the apparatus shall be deemed to have failed the test.

A functional description and a definition of performance criteria, during or as a consequence of the EMC testing, shall be provided by the manufacturer and noted in the test report, based on the following criteria:

Performance criterion A: The apparatus shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. The performance level may be replaced by a permissible loss of performance. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, either of these may be derived from the product description and documentation, and from what the user may reasonably expect from the apparatus if used as intended.

Performance criterion B: The apparatus shall continue to operate as intended after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. The performance level may be replaced by a permissible loss of performance. During the test, degradation of performance is however allowed. No change of actual operating state or stored data is allowed. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, either of these may be derived from the product description and documentation, and from what the user may reasonably expect from the apparatus if used as intended.

Performance criterion C: Temporary loss of function is allowed, provided the function is self-recoverable or can be restored by the operation of the controls.

5 Management of EMC

The railway is a complex installation with moving sources of electromagnetic energy and the application of the EMC standards in the EN 50121 series is not a guarantee of satisfactory performance. There may be cases where apparatus has to be positioned in restricted spaces or added to an existing assembly, with the possible creation of environments of unusual severity. All cases shall be considered with respect to a formal plan for the management of EMC. This plan should be established at as early a stage of the project as is possible.

The EU Directive 91/440/EEC on the development of the Community's railway lays down that management of the railway infrastructure for mainline passenger operations shall be separated from train operation. This creates an interface between these two entities.

Refer to EN 50238 for defining the management process to comply with this requirement.

Annex A
(informative)

The railway system

A.1 Introduction

For operating purposes, railways use electrical systems that require very high outputs (up to several MVA) and power electronic systems that are characterised by their non-linearity (producing harmonics).

In an electric railway, the trains have to be supplied via sliding contacts from a supply line, called the catenary or overhead, or a trackside conductor rail, which is installed along the track. The current generally returns to the substation via the rails, a separate return conductor or via the earth. The railway is an integrated system in which electricity has many uses in addition to train propulsion including:

- heating, air conditioning, catering and lighting of passenger coaches with converters on the vehicles. This power is fed along the train by separate conductors;
- signalling and telecommunication systems along the track and between control centres, concerned with the movement of trains;
- computer installations in control centres, linked via trackside routes;
- passenger information systems on vehicles, stations and depots;
- traction within diesel-electric locomotives and multiple units;
- battery traction vehicles.

Hence, problems of EMC arise not only within the locomotive and the power supply but also in these associated systems. Non-electrified traction such as diesel electric traction may also be a source of EM noise.

The normal and disturbed working of these systems may be a source of electromagnetic noise which can affect all other systems.

A.2 General coupling mechanisms

The coupling between systems is by the well known physical phenomena and limits are expressed in terms of these phenomena.

Five modes of coupling are distinguished:

- electrostatic coupling, in which a charged body is discharged to a victim circuit;
- capacitive coupling, in which the varying voltage in one circuit produces voltage changes in a victim circuit via mutual capacitance;
- Inductive coupling, in which a varying magnetic field produced by a current in one circuit, links with a victim circuit, inducing a voltage via mutual inductance;
- conductive coupling, in which the source and victim circuits share a common conduction path;
- electric (E) and magnetic (H) radiation, in which the circuit structures act as antennas transmitting and receiving energy.

A.3 Principal electromagnetic phenomena for immunity

A.3.1 Conducted low frequency phenomena

Slow variations of the supply voltage including dips, surges, fluctuations, unbalance, harmonics, intermodulation products, data transfer carried on the power supply, power frequency variations, induced low frequency voltages and d.c. in a.c. networks.

A.3.2 Low frequency field phenomena

Magnetic fields, both steady and transient. Electric fields.

A.3.3 Conducted high frequency phenomena

Unidirectional and oscillatory transients, as single events or repetitive bursts. Induced currents.

A.3.4 Radiated high frequency phenomena

Magnetic fields. Electric fields. Radio frequency radiated waves.

A.4 Principal electromagnetic phenomena for emission

In principle, the same phenomena exist as are listed for immunity, but limits have only been applied to the following:

- magnetic fields produced by power frequency and harmonic frequency currents, up to 9 kHz;
- voltage fluctuations produced by power frequency and harmonic currents;
- radio frequency fields produced by trains.

A.5 Description of the different electric traction systems

Direct current and alternating current sources are used.

d.c. systems include:

High voltage	:	3 000 V
Medium voltage	:	1 500 V
Low voltage	:	from 600 V to 1 400 V, including more particularly urban transit systems.

a.c. systems include:

Industrial Frequency	:	50 Hz at 25 kV or Autotransformer 50/25 kV
Low frequency	:	16,7 Hz at 15 kV.

Isolated three phase lines exist with two overhead conductors.

A.6 Components of electric traction systems

Traction power is generally supplied from the high voltage national or railway grid systems at voltages up to 400 kV. Connection points, known as sub-stations, perform the following functions:

- protection (circuit breakers) for both public and railway interests;
- adaptation of voltage level by transformer;
- possible rectification to provide d.c. supply or frequency conversion to give low frequency supply.

The power obtained by this means is transmitted to the traction vehicle via a system of flexible-suspension contact lines (known as the overhead catenary) with which a locomotive-mounted articulated device (known as the pantograph) is brought into contact. On low voltage lines, a trackside conductor rail may be provided from which power is collected by a sliding contact (known as the collector shoe).

On the traction vehicle, the power is regulated and supplied to electric motors to control the movement of the train. Auxiliary power is also regulated and, although of lower power than that supplied to the electric traction motors, can still be a significant source of electromagnetic noise.

On a.c. lines, circuit components may be added to the traction supply lines (auto-transformers or booster transformers) to reduce the magnetic field and hence the induced voltage in telecommunication circuits.

A.7 Internal sources of electromagnetic noise

There are several rail-specific components which produce electromagnetic noise. These include:

A.7.1 Static elements

The overhead line of the railway and the high voltage line feeding the substation can be the source of high or low frequency noise.

Among the phenomena which are involved in RF emission are:

- the corona effect, where ionisation of neutral molecules in the electric field close to the conductors produces RF noise. This can exist along the whole alignment;
- brush discharges in zones of high voltage gradient on the surface of insulators;
- discharge type micro-arcs at bad contacts between energised metallic parts. These effects are local and attenuate rapidly with distance;
- partial flashovers across dry bands of polluted insulator surfaces.

Railway overhead systems differ from most high voltage overhead lines by being closer to the ground, having more insulators and having less natural cleaning of the insulators.

Low frequency noise can be significant within a wide zone, up to 3 km (or more if the ground resistivity is high). It is produced transiently at substations when high voltage switching takes place, is distributed along the overhead when it is energised, is enhanced when non-linear traction loads such as rectifiers are supplied, and is stimulated locally when flashover takes place. If a d.c. traction system is used, low frequency harmonics are produced by the rectifier substation.

A.7.2 Mobile elements

Motive power units (electric locomotives or multiple unit coaches) are a source of electromagnetic noise during routine working, primarily controlled by the following equipment:

- power control systems using controlled semiconductors such as thyristors, GTO’s and IGBT’s. These produce energy, which give either direct radiation from the vehicle components or indirect radiation via the power supply lines. An overhead line can act as an antenna;
- auxiliary apparatus on traction vehicles may have relatively high power rating and must be considered as a source of noise;
- the sliding contact between the line and the pantograph (or shoe and rail). This collection is via a series of short arcs which act as radio sources;
- special case arcing and transients which are produced when the pantograph is raised or lowered, or the vehicle circuit breaker is closed or opened.

Diesel-electric locomotives should be included since they can contain semiconductor power control which can generate noise. Such locomotives also contain auxiliary systems which may be sources.

A.7.3 Auxiliary power converters

Coaching stock air conditioning, catering and similar systems may be supplied via a semiconductor static converter and these may be sources of noise. These converters may be on several coaches in a train and the summation of their noise must be considered.

A.7.4 Train line

The locomotive supplies power, generally at voltages less than or equal to 1 500 V, sometimes at 3 000 V, at powers up to 800 kW, to the electric systems of the train for lighting, heating, air-conditioning, battery charging, and converters through a conductor (termed “train line”). This current, which can be 800 A, is a source of noise to adjacent equipment.

This auxiliary current may return to the locomotive via the rails and hence have an influence on apparatus on the track. Train lengths of several hundred metres are not unusual.

A.7.5 Traction return current with respect to track circuits

An electrical supply (continuous, alternating or pulse) is connected across the running rails, in what is known as a track circuit. When a train travels on the track, its axles short-circuit a detector of this electrical supply and the presence of the train is detected. Electrical noise may energise the detector although the train is present, giving a false indication of clear track. Track circuits take many forms with some having frequency and time coding to reduce the risk of false energisation.

Since the power supply may contain voltage components at track circuit frequencies, the input impedance of the train may have to be greater than a specified value. This prevents the passage of currents at track circuit frequencies in the running rails. The traction and auxiliary equipment on the vehicle and the substations shall not generate currents at track circuit frequencies which exceed specified values. Limits are applied for particular cases. These effects are entirely internal to the railway and many different cases can exist.

A.7.6 Trackside equipment

Electricity is used in trackside cabinets to drive switch motors, heating and train pre-heating as well as other apparatus. Although of relatively low power, these elements are close to the line and may affect other railway apparatus.

A.8 Summary of main characteristics of railways

The essential differences between electric railways and other large electric networks are:

- a very wide variety of power supply configurations;
- a very wide variety of power use and control systems and sub-systems;
- the use of sliding contacts to convey high powers to the moving trains;
- the high speed of some trains;
- the presence of several moving sources within the same zone of influence;
- a fluctuating and imprecise system of current flow to and from the train, including the passage of current via the ground;
- high single phase loads which may cause imbalance in the three phase system;
- the possibility of simultaneous generation of disturbance from several sources;
- generation of EM noise over a wide frequency spectrum;
- the interaction of supply and vehicles to enhance or diminish the effect at any given frequency.

A.9 External sources of disturbance

The railway is distributed through the public domain and is exposed to various sources of EM noise at various places.

These include

- neighbouring railway systems;
- trackside radio stations (e.g. GSM-R system), sometimes operating at high powers;

- portable radio transmitters including portable telephones;
- adjacent overhead power lines from which power frequency induction may be experienced;
- radar sets at airports, on aircraft, in military use;
- industrial plants which disturb the electricity supply network.

Annex ZZ
(informative)

Coverage of Essential Requirements of EC Directives

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and within its scope the standard covers all relevant essential requirements as given in Article 4 of the EC Directive 89/336/EEC.

Compliance with this standard provides one means of conformity with the specified essential requirements of the Directive concerned.

WARNING: Other requirements and other EC Directives may be applicable to the products falling within the scope of this standard.

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W4 4AL