Railway applications — Electromagnetic compatibility —

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

The European Standard EN 50121-3-1:2006 has the status of a British Standard

ICS 29.020; 29.280; 45.060.01

British Standards

National foreword

This British Standard was published by BSI. It is the UK implementation of EN 50121-3-1:2006. It supersedes BS EN 50121-3-1:2000 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/9, Railway electrotechnical applications.

A list of organizations represented on GEL/9 can be obtained on request to its secretary.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 29 September 2006

ISBN 0 580 49112 9

Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 50121-3-1

July 2006

ICS 29.020; 29.280; 45.060.01

Supersedes EN 50121-3-1:2000

English version

Railway applications - Electromagnetic compatibility Part 3-1: Rolling stock - Train and complete vehicle

Applications ferroviaires -
Compatibilité électromagnétique
Partie 3-1: Matériel roulant -
Trains et véhicules complets

Bahnanwendungen -
Elektromagnetische Verträglichkeit
Teil 3-1: Bahnfahrzeuge -
Zug und gesamtes Fahrzeug

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

Ref. No. EN 50121-3-1:2006 E

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 50121-3-1 on 2006-07-01.

This European Standard supersedes EN 50121-3-1:2000.

This European Standard is to be read in conjunction with EN 50121-1.

This standard forms Part 3-1 of the European Standard series EN 50121, published under the general title "Railway applications - Electromagnetic compatibility". The series consists of:

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

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.

Contents

Introduction

High powered electronic equipment, together with low power microcontrollers and other electronic devices, is being installed on trains in great numbers. Electromagnetic compatibility has therefore become a critical issue for the design of train related apparatus as well as of the train as a whole.

This Product Standard for rolling stock sets limits for electromagnetic emission and immunity in order to ensure a well functioning system within its intended environment.

Immunity limits are not given for the complete vehicle. Part 3-2 of this standard defines requirements for the apparatus installed in the rolling stock, since it is impractical to test the complete unit. An EMC plan shall be established for equipment covered by this standard.

1 Scope

This European Standard specifies the emission and immunity requirements for all types of rolling stock. It covers traction stock and trainsets including urban vehicles for use in city streets.

The frequency range considered is from d.c. to 400 GHz. No measurements need to be performed at frequencies where no requirement is specified.

The scope of this part of the standard ends at the interface of the rolling stock with its respective energy inputs and outputs. In the case of locomotives, trainsets, trams etc., this is the current collector (pantograph, shoe gear). In the case of hauled stock, this is the a.c. or d.c. auxiliary power connector. However, since the current collector is part of the traction stock, it is not entirely possible to exclude the effects of this interface with the power supply line. The slow moving test has been designed to minimise these effects.

Basically, all apparatus to be integrated into a vehicle shall meet the requirements of Part 3-2 of this standard. In exceptional cases, where apparatus meets another EMC Standard, but full compliance with Part 3-2 is not demonstrated, EMC shall be assured by adequate integration measures of the apparatus into the vehicle system and/or by an appropriate EMC analysis and test which justifies deviating from Part 3-2.

The electromagnetic interference concerning the railway system as a whole is dealt with in EN 50121-2.

These specific provisions are to be used in conjunction with the general provisions in EN 50121-1.

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 50121-1	Railway applications - Electromagnetic compatibility Part 1: General
EN 50121-2	Railway applications - Electromagnetic compatibility Part 2: Emission of the whole railway system to the outside world
EN 50121-3-2	Railway applications - Electromagnetic compatibility Part 3-2: Rolling stock - Apparatus
EN 50238	Railway applications - Compatibility between rolling stock and train detection systems
EN 55016-1-1	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus (CISPR 16-1-1)
ITU-T	Directive concerning the protection of telecommunication lines against harmful effects from electrical power and electrified railway lines Volume VI: Danger and disturbances

3 Definitions

For the purpose of this Part 3-1 of the European Standard, the following definitions apply:

3.1
traction stock
electric and diesel locomotives, high speed trainsets, electric and diesel multiple units (no locomotive, each coach has its own traction equipment) for main line vehicles, Light Railway Vehicles (LRV) such as underground trainsets, trams, etc. for urban vehicles

3.2
hauled stock
all independent passenger coaches and freight wagons (if they contain electric apparatus such as freezing equipment) which may be hauled in random combinations by different types of locomotives

3.3
main line vehicles
vehicles such as high speed trains, suburban trains, freight trains, mainly designed to operate between cities

3.4
urban vehicles
vehicles such as underground trainsets, trams, LRV (Light Rail Vehicles), trolleybuses, mainly designed to operate within the boundary of a city

4 Applicability

Generally, it is not possible to test electromagnetic compatibility invoking every function of the stock. The tests shall be made at typical operating modes considered to produce the largest emission.

The configuration and mode of operation shall be specified in the test plan and the actual conditions during the tests shall be precisely noted in the test report.

5 Immunity tests and limits

No tests are applied to the complete vehicle, but the immunity tests and limits in Part 3-2 of this standard were selected in the knowledge that the vehicle can be deemed to be immune to a level of 20 V/m over the frequency range 0,15 MHz to 2 GHz. It is expected that the assembly of the apparatus into a complete vehicle will give adequate immunity, provided that an EMC plan has been prepared and implemented, taking into account the limits in Part 3-2 of this standard.

6 Emission tests and limits

The emission tests and limits for rolling stock in this standard should ensure as far as possible that the rolling stock does not interfere with typical installations in the vicinity of the railway system.

Measurements shall be performed in well-defined and reproducible conditions. It is not possible to totally separate the effects of the railway system and the stock under test. Therefore, the operator and the manufacturer have to define in the contract the test conditions and the test site for compatibility with signalling and communication systems and for interference on telecommunication lines, (e.g. load conditions, speed and configuration of the units). For radiated emissions, the test conditions are defined in 6.3.1 and 6.3.2. The contributions of other parts of the railway system (e.g. substations, signalling) and of the external environment (e.g. power lines, industrial sites, radio and television transmitters) to the measurements must be known and taken into account.

6.1 Compatibility with signalling and communication systems

Signalling, train radio and other railway systems (axle counters, track circuits, train control systems, etc.) are different in every country in terms of operating frequencies and waveforms. Therefore, emission requirements shall be specified according to the type of signalling and communication systems used (see EN 50238).

The requirements need to take into account sources of disturbance other than the rolling stock, including the train radio and signalling systems themselves, and the effects of transients due to bad contact, pantograph bouncing, third rail gaps, etc.

6.2 Interference on telecommunication lines

6.2.1 Digital telecommunication lines

Interference with digital systems such as PCM, ISDN, is not covered in this standard.

6.2.2 Analogue telecommunication lines

The harmonics in the traction current of a railway system may induce noise in a conventional analogue telecommunication system. The acceptable level of noise on conventional analogue telephone lines is specified by ITU-T. The value of this noise is measured with a psophometric filter. The relationship between the current absorbed or generated by the traction vehicle and the noise in the telephone line is neither under the total control of the vehicle manufacturer nor of the operator of the network (For details see A.1). Thus it shall be the responsibility of the purchaser of the tractive stock in accordance with the rules of the Infrastructure Controllers to specify a frequency weighted current limit at the vehicle interface.

One method commonly used is to specify the psophometric current I_{pso} which has a psophometrical frequency weighting. The background and application of this method is described in Annex A. As it is known that the I_{pso} method does not fully represent the noise effect of the harmonics in the kHz range, alternative methods of frequency weighting may be specified by the purchaser.

6.3 Radiated electromagnetic disturbances

6.3.1 Test site

The test site shall meet as far as possible the “free space“ requirements below within the existing constraints of the railway environment;

- No trees, walls, bridges, tunnels or vehicles shall be close to the measurement point, minimum separation distance:

  30 m for main line vehicles
  10 m for urban vehicles

- Since it is impossible to avoid the support masts of the overhead, the measurement point shall be at the midpoint between masts, on the opposite side of the track (in case of a double track, on the side of the track which is being used). If the railway system is powered by a third rail, the antenna shall be on the same side of the track (worst case).

- The overhead/third rail should be an “infinite“ line on both sides of the measurement point, the minimum clear length on both sides of the measurement point should be:

  3 km for main line vehicles
  500 m for urban vehicles

  Overhead/third rail discontinuities as well as substations, transformers, neutral sections, section insulators etc. should be avoided.

Since resonances may occur in the overhead line at radio-frequencies, it may be necessary to change the test site. The exact location of the test site and features of both the site and the overhead system layout shall be noted.

The contribution of the substation may be considered when assessing the emissions from the vehicle. Note that the contribution of a dc substation depends on its load current and will not be measured properly in a no-load condition.

- Close proximity to power lines including buried lines, substations, etc. should be avoided.

- No other railway vehicle should be operating in the same feeding section or within a distance of:

  20 km for main line vehicles
  2 km for urban vehicles

  If these conditions are not possible, the ambient noise before and after each emission measurement of the vehicle under test shall be recorded. Otherwise only two ambient noise measurements at the beginning and the end of the test series are sufficient.

  If at specific frequencies or in specific frequency ranges the ambient noise is higher than the limit values less 6 dB, the measurements at these frequencies need not be considered. These frequencies shall be noted in the test report.

6.3.2 Test conditions

The tests shall cover the operation of all systems onboard the rolling stock which may produce radiated emissions.

Hauled stock shall be tested while stationary in an energised mode (auxiliary converters, battery chargers, etc. in operation). The antenna should be sited opposite the equipment expected to produce the greatest emissions at the frequencies under measurement.

Traction stock shall be tested whilst stationary and at slow moving speed. During the stationary test, the auxiliary converters shall operate (it is not inevitably under maximum load conditions that the maximum emission level is produced) and the traction converters shall be under voltage but not operating. The antenna should be sited opposite the vehicle centre line unless an alternative location is expected to produce higher emission levels.

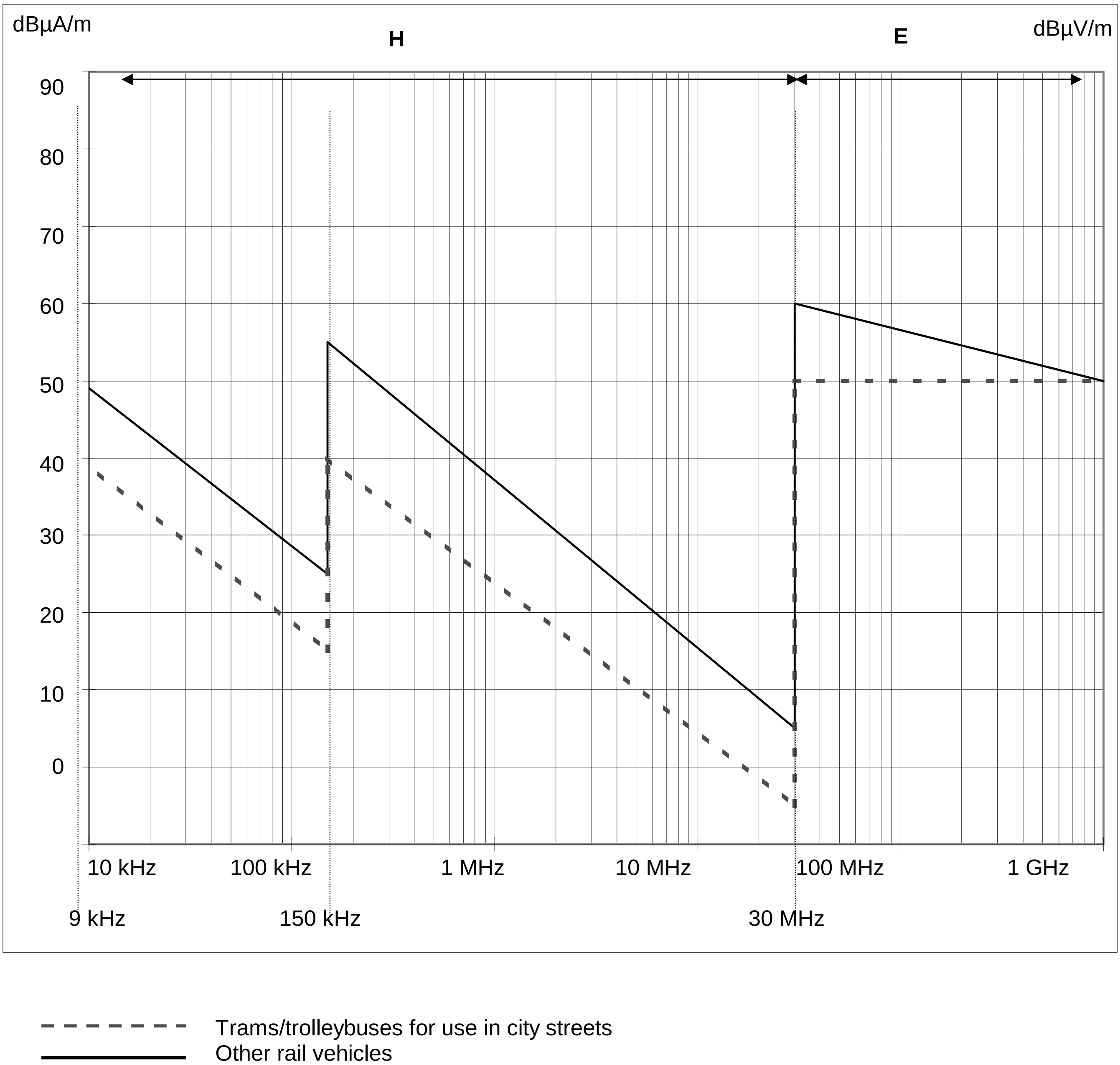
For the slow moving test, the speed shall be low enough to avoid arcing at or bouncing of the sliding contact and high enough to allow for electric braking. The recommended speed range is (20 ± 5) km/h for urban vehicles and (50 ± 10) km/h for main line vehicles. When passing the antenna, the vehicle shall accelerate or decelerate with approximately 1/3 of its maximum tractive effort within the given speed range.

The slow moving test may be replaced by a stationary test with the vehicle operating at 1/3 of its maximum tractive effort against the mechanical brakes, if the following conditions are fulfilled:

– the traction equipment allows for operation whilst stationary
– tests of electric braking are not required, if no different circuits are used in braking.

If the slow moving test is replaced by a stationary test with tractive effort, then the slow moving limits shall be applied. The decision for the stationary test with tractive effort has to be justified in the test report.

6.3.3 Emission limits

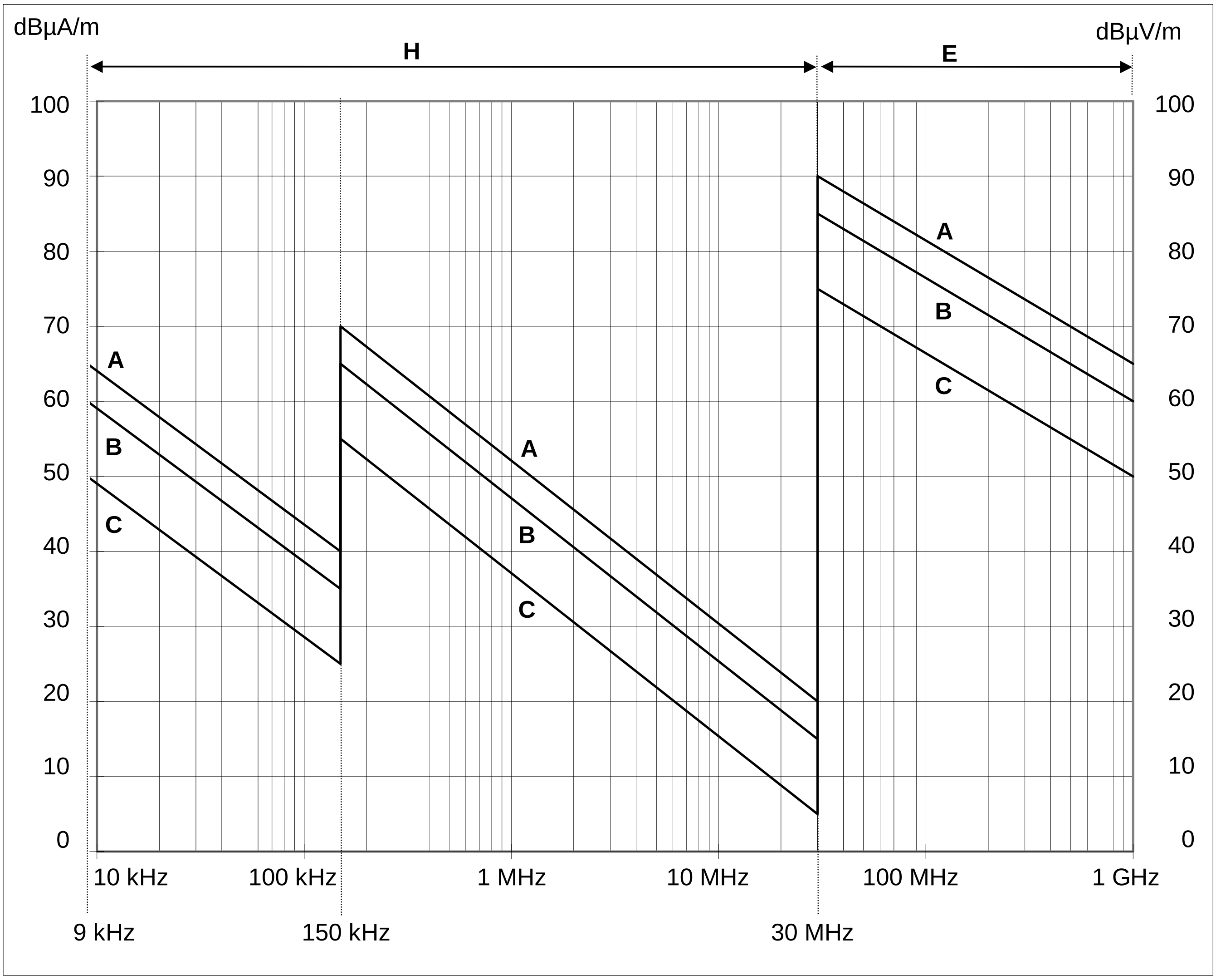


NOTE 1 The limits are defined as quasi-peak values and the bandwidths are those used in EN 55016-1-1:

	Bandwidth
Frequencies up to 150 kHz	200 Hz
Frequencies from 150 kHz to 30 MHz	9 kHz
Frequencies above 30 MHz	120 kHz

NOTE 2 All values are measured at a distance of 10 m.

Figure 1 - Limits for stationary test (QP, 10 m)



NOTE 1 Emission limits
A = 25 kV a.c.
B = 15 kV a.c., 3 kV d.c. & 1,5 kV d.c.
C = 750 V & 600 V d.c., including trams/trolleybuses for use in city streets

NOTE 2 For details of test procedure, see Annex B.

NOTE 3 All values measured at a distance of 10 m in peak values.

NOTE 4 For diesel and diesel electric locomotives and multiple units, the emission limits of Figure 1 (“other rail vehicles”) and C in Figure 2 shall apply.

Figure 2 - Limits for slow moving test (Peak, 10 m)

Annex A
(informative)

Interference on telecommunication lines

A.1 Relationship between currents in railway system and noise on telecommunication lines

Conventional telecom copper cables in the vicinity of electrified railway lines are subject to electromagnetic disturbances caused by the currents in the railway system.

These disturbances result in induced longitudinal voltages ranging from the frequency of the fundamental wave to higher frequency harmonics. Sources of the harmonics are converters applied within the traction equipment of the traction stock and/or in the power supply station. Due to imbalances in the cable itself, these longitudinal voltages translate to transverse voltages or noise.

The acceptable level of noise on conventional analogue telephone lines is specified by the ITU-T. The value of this noise is measured with a psophometric filter.

The relationship between the current absorbed by the traction vehicle and the noise on the telecom line is neither under the total control of the vehicle manufacturer nor of the railway and telecommunication network operators.

This relationship depends on:

- the structure of the telecom cables
  - shielding, isolation to ground, balance of the cable;
- the characteristics of the telecom terminals
  - susceptibility, input balance;
- the topology of the telecom network
  - length of parallel sections of the telecom line to the tracks;
  - the distance between tracks and telecom lines;
  - the earth-resistivity;
- the topology of the railway network
  - single/double track;
- the type of power supply of the catenary
  - a.c./d.c.;
  - substation ripple (d.c. rectifiers or a.c. 16,7 Hz static converters in some cases);
  - type of catenary and feeder system (e.g. 1 x 25 kV or 2 x 25 kV);
  - application of return conductors;
  - single-end or double-end supply of the section under consideration;
- the density of train circulation;
- the current absorption and generation of harmonics of the tractive stock;
- the kind of harmonics superposition from a number of converters.

A.2 Psophometric current definition

The psophometric current is an equivalent disturbance current, which represents the effective disturbance of a current spectrum in a power circuit to a telephone line. It is defined by the equation:

$$I_{\mathrm{pso}} = \frac{1}{p_{800}} \sqrt{\sum (p_{\mathrm{f}}\ I_{\mathrm{f}})^2}$$

where:

I_{f} is the current component at frequency f in the contact line current.

p_{f} is the psophometric weighting.

The values of p_f may be found in the ITU-T Directive „Protection of telecommunications lines against harmful effects from electrical power and electrified railway lines“ (ITU-T O.41).

For measurement purposes, voltage and ampere meters which automatically calculate the signal according to these values of p_f by means of a psophometric filter are available.

A.3 Limits and test conditions

It shall be the responsibility of the purchaser to specify the maximum value of the psophometric current, and the conditions under which it is defined, including duration.

The following conditions shall be covered:

- Limits of I_{pso} under normal and under reduced performance conditions (one or more traction converters temporarily out of service)

- In the case of d.c. supply:

  d.c. railways are normally fed by diode rectifiers from the 3-phase mains supply. Ideally, a single bridge rectifier produces a 6-pulse shape of voltage (i.e. first harmonic at 300 Hz in a 50 Hz mains) or two bridges produce a 12-pulse shape (i.e. 600 Hz). Due to imbalances in the rectifier and due to induction, a fundamental component at 50 Hz is commonly found.

  The presence of filters in the substation greatly reduces the effect of the substation.

  Nevertheless, in d.c. systems, the substation is the main source of perturbation.

  Thus, to qualify a traction vehicle, the contribution of the rectifier unit and filters of the fixed installation shall be taken into account.

  It shall also be necessary to take into account the distance between the traction vehicle and the substation which affects the line inductance.

- In the case of a.c. supply:

  If the line voltage distortion has to be taken into consideration, the essential harmonics shall be specified. If special resonance conditions in the catenary system shall be taken into account, it shall be necessary to specify the relevant data. Otherwise the situation of the vehicle nearest to the supply station is assumed to give the highest value I_{pso}.

A.4 Measurement of the psophometric current

During acceptance tests or investigation tests, the disturbance current I_{pso} shall be measured on board the traction vehicle. Existing current sensors of the vehicle may be used, if their frequency response is sufficient (at least up to 5 kHz). In the case of an a.c. system, the current shall be picked up on the high voltage side of the transformer primary winding, and not on the ground side, as the transformer may have a resonant frequency below 10 kHz.

The psophometric current shall be measured by means of a psophometer or another adequate system which uses filtering according to the psophometric weighting factor p_f.
To obtain additional information about the composition of the spectrum and the sources of disturbance, the use of a dual channel spectrum analyser, applied to vehicle input current and input voltage, is strongly recommended.
The psophometric current shall be measured in normal and in reduced operation mode (not all converters operating). The interpretation of the measurement results shall take into consideration the influence of operating conditions as well as changes in line inductance and supply voltage.

Effects due to transients (switching in the power circuits, pantograph bouncing, third rail/fourth rail gaps etc.) shall be kept out of the evaluation.

A.5 Calculation of the overall psophometric current of a trainset

Typically, the total current of a trainset is not available. Instead of installing a special measuring system which can generate an image of the total current from sensors distributed over the whole trainset, it is normally sufficient to pick up the current of one tractive unit of the trainset.

If the psophometric current is being measured at one power terminal of a trainset and this trainset has „n“ terminals, the overall current shall be calculated according to the following rules:

A.5.1 D.C. systems

D.C. railways are normally fed by diode rectifiers from the three phase supply. If no special filters are applied, the ripple of the rectifier output contributes considerably to the psophometric current absorbed by vehicles in the supply section.

- **d.c. systems with dominating rectifier ripple**

  (Vehicles with camshaft control; vehicles with chopper or inverter control, substation with 6-pulse rectifier without filtering)

  $I_{\text{pso (total)}} = n \times I_{\text{pso (one unit)}}$

- **d.c. systems with converters on the vehicle and low rectifier ripple**

  $I_{\text{pso (total)}}$ may be less than $I_{\text{pso (one unit)}}$, for choppers operating in interlaced mode

  $I_{\text{pso (total)}} = \sqrt{n} \times I_{\text{pso (one unit)}}$, for choppers operating without synchronisation or for inverters directly connected to the power supply.

A.5.2 A.C. systems

The psophometric current generated by vehicles in the supply section depends mainly on the type of converter used on board the vehicle.

- **a.c. systems with phase controlled converters**

  $I_{\text{pso (total)}} = \sqrt{n} \times I_{\text{pso (one unit)}}$. This seems to be based on a statistical mix of vehicle types, speeds and actual current consumption. But recent experience with high power trainsets shows that this $\sqrt{n}$-law is not applicable in the case of equal speeds, equal power and equal vehicle types, when $I_{\text{pso (total)}} = n \times I_{\text{pso (one unit)}}$ applies

- **a.c. systems with 4 quadrant converters (4QC, pulse width modulated line converter)**

  $I_{\text{pso (total)}} < I_{\text{pso (one unit)}}$, if 4QC operate in interlaced mode (normal operating condition)

  $I_{\text{pso (total)}} = n \times I_{\text{pso (one unit)}}$, if n equal units operate in non interlaced mode.

Annex B
(normative)

Radiated electromagnetic disturbances - Test procedure

B.1 Purpose

This annex describes a measurement method for evaluation and qualification of a complete railway vehicle or train concerning the noise generated in the range 9 kHz - 1 GHz. It fulfils most of the EN 50121-2 measurement method recommendations but provides simplified features which significantly reduce the whole test duration.

B.2 Measuring equipment and test method

To reduce test duration, the frequency scanning technique is used. This can be done either by a spectrum analyser or a computer controlled receiver. Each frequency range is divided into several subranges.

Each evaluation of a train or a vehicle consists in doing a test of each subrange.

The apparatus shall scan this subrange continuously and memorise the maximum values reached during the test. This can be achieved by the „peak hold“ function or under computer control of the apparatus. This method assumes that the level and characteristics of electromagnetic noise do not vary significantly during each scan.

The position, location, type and other features concerning the antennas are the same as described in EN 50121-2.

The measuring apparatus shall be in accordance with the EN 55016-1-1 requirements described in Subclause 4.2: „Peak measuring receivers for the frequency range 9 kHz to 1 GHz“. However, for the 9 kHz to 150 kHz range (band A), the 200 Hz bandwidth may give the following problems.

- it is not always available in standard spectrum analysers;
- the scan duration is excessive for moving sources;

  this would make it necessary to multiply the number of subranges which is contrary to the objective of the method.

For these reasons, the bandwidth for band A may be higher and 1 kHz is a convenient value. Proper corrections shall be carried out on the measurement results assuming that the noise is a broad band white noise.

Table B.1 may be used as a guideline for the test:

Table B.1 - Guideline for test

Band	Subrange Hz	Span [a] Hz	Bandwidth kHz	Sweep time [b] ms
A	9 k - 59 k	50 k	1	300
	50 k - 150 k	100 k	1	300
B	150 k - 1,15 M	1 M	9 or 10	37
	1 M - 11 M	10 M	9 or 10	370
	10 M - 20 M	10 M	9 or 10	370
	20 M - 30 M	10 M	9 or 10	370
C/D	30 M - 230 M	200 M	100 or 120	42
	200 M - 500 M	300 M	100 or 120	63
	500 M - 1 G	500 M	100 or 120	100

[a] for a spectrum analyser

[b] may be slightly different from one instrument to another

NOTE If using a standard low cost spectrum analyser, care shall be taken to always use the apparatus within the manufacturer guaranteed limits (input attenuation, intermediate frequency gains,...) and ensure a proper calibration. It also may be necessary to check the accuracy of the instrument over the whole frequency range with a reference signal prior to testing.

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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