

INTERNATIONAL STANDARD



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



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INTERNATIONAL STANDARD



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

INTERNATIONAL
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ELECTROMAGNETIC COMPATIBILITY –****Part 3-1: Rolling stock – Train and complete vehicle****FOREWORD**

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International Standard IEC 62236-3-1 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This third edition cancels and replaces the second edition published in 2008. It constitutes a technical revision and has been developed on the basis of EN 50121-3-1:2015.

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

- a) clarification of scope (Clause 1);
- b) clarification of definitions (Clause 3);
- c) clarification of applicability (Clause 4);
- d) clarification of interference on outside party telecommunication lines (6.2), psophometric current (Annex A);
- e) moving emission values for radiated H-field in the frequency range 9 kHz to 150 kHz into new Annex C due to the fact that:
 - there are very few outside world victims (e.g. radio services),
 - the radiated emission measured at 10 m is not representative of the compatibility with internal railway apparatus,
 - the EMC with other railway apparatus in this frequency range is covered in other procedures and standards like IEC 62427 series,
 - there is low reproducibility.

This International Standard is to be read in conjunction with IEC 62236-1.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
9/2337/FDIS	9/2367/RVD

Full information on the voting for the approval of this International Standard 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.

A list of all parts in the IEC 62236 series, published under the general title *Railway applications – Electromagnetic compatibility*, 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.

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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 series defines requirements for the apparatus installed in the rolling stock, since it is impractical to test the complete unit. An EMC plan ~~should be established for~~ includes equipment covered by this document.

RAILWAY APPLICATIONS – ELECTROMAGNETIC COMPATIBILITY –

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

1 Scope

This part of IEC 62236 specifies the emission and immunity requirements for all types of rolling stock. It covers traction stock, **hailed stock** and trainsets including urban vehicles for use in city streets. **This document specifies the emission limits of the rolling stock to the outside world.**

The scope of this document ends at the interface of the rolling stock with its respective energy inputs and outputs. In the case of ~~locomotives~~ **traction units**, trainsets, trams, etc., this is the current collector (pantograph, shoe gear). In the case of hailed stock, this is the AC or DC 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 minimize these effects.

~~Basically, all apparatus to be integrated into a vehicle should 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 should 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.~~

There may be additional compatibility requirements within the railway system identified in the EMC plan (e.g. as specified in IEC 62427).

~~The electromagnetic interference concerning~~ **Electromagnetic emissions** of the railway system as a whole ~~is~~ **are** dealt with in IEC 62236-2.

These specific provisions are ~~to be~~ used in conjunction with the general provisions in IEC 62236-1.

The frequency range considered is from 0 Hz (DC) to 400 GHz. No measurements need to be performed at frequencies where no requirement is specified.

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 62236-1:2018, *Railway applications – Electromagnetic compatibility – Part 1: General*

IEC 62236-2:2018, *Railway applications – Electromagnetic compatibility – Part 2: Emission of the whole railway system to the outside world*

IEC 62236-3-2:2018, *Railway applications – Electromagnetic compatibility – Part 3-2: Rolling stock – Apparatus*

~~IEC 62427, Railway applications — Compatibility between rolling stock and train detection systems~~

CISPR 16-1-1:2015, Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus

~~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 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

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

3.1.1

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~~

electric and diesel traction unit, high speed trainset, elementary fixed combination of traction stock and hauled stock, electric and diesel multiple unit (no traction unit, distributed traction equipment), Light Railway Vehicle (LRV), such as tram, trolley bus or any other electrical vehicle for urban mass transit, underground trainset

3.1.2

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~~ traction units

3.1.3

main line vehicles

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

3.1.4

urban vehicles

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

3.2 Abbreviated terms

AC	Alternating current
BW	Band width
DC	Direct current
E	Electric (field)
EMC	Electromagnetic compatibility
EUT	Equipment under test

H	Magnetic (field)
ISDN	Integrated Services Digital Network
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
LRV	Light rail vehicle
PCM	Pulse – code modulation
QC	Quadrant converters
QP	Quasi-Peak
xDSL	All types of <i>digital subscriber lines</i>

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 typical operating mode shall require all systems to be energised which are normally in continuous operation during service. It is not necessary during the test to exercise systems which operate transiently such as for example operation of internal doors, although they should be energised. It is not necessary to test degraded modes of operation.

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~~ requirements

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~~ requirements in IEC 62236-3-2.

In exceptional cases, where apparatus meets another EMC Standard, but full compliance with IEC 62236-3-2 is not demonstrated, EMC shall be ensured by adequate integration measures of the apparatus into the vehicle system and/or by an appropriate EMC analysis and test which justifies deviating from IEC 62236-3-2.

6 Emission tests and limits

6.1 General

The emission tests and limits for rolling stock in this document 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~~

NOTE 1 Signalling and communication, 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 compatibility requirements ~~shall be~~ are specified according to the type of signalling and communication systems used ~~(see IEC 62427).~~

NOTE 2 There can be cases in which radio or other railway external services with working frequencies below 150 kHz are in operation close to the railway. The EMC plan covers these cases and an adequate level of emission from railway on these working frequencies may be found in the values given in informative Annex C, hence no guarantee can be given for an undisturbed operation.

~~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 outside party telecommunication lines

6.2.1 Digital telecommunication lines

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

It should be noted that these systems operate in a higher frequency range using multiple carriers and various automatic error correction protocols.

It is considered unlikely that rolling stock can produce sufficient interference in this frequency range.

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 Clause 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.~~

No harmonized limits apply.

Information about interference on telecommunication lines can be found in Annex A.

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;~~

It can be assumed that measurements will not take place in laboratory conditions. Trees, walls, bridges, tunnels or other conductive objects in the vicinity of the measurement antenna could have an impact on the measurement. Other railway vehicles operating in the same feeding section or nearby the measuring point may affect the measurement result. Overhead/third rail discontinuities as well as substations, power lines, buried lines, transformers, neutral sections, section insulators, etc., close to the measuring point may cause additional variations.

These influences shall be reduced as far as practical but in any case no obstacles above rail level which may influence the measurements shall be located between antenna and EUT.

The overhead/third rail should be a continuous line as far as practical on both sides of the measurement point (typically at least 200 m).

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.~~

At the beginning and at the end of the test series the ambient noise shall be recorded. This measurement shall be done without any influence of the vehicle.

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

NOTE It is helpful to perform this ambient noise measurement also with the vehicle completely powered down in front of the antenna.

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 (a representative version) 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.

Tests for identical coaches or wagons are performed only once.

Traction stock shall be tested while 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~~ shall be ~~sited opposite~~ in front of the middle of each 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:

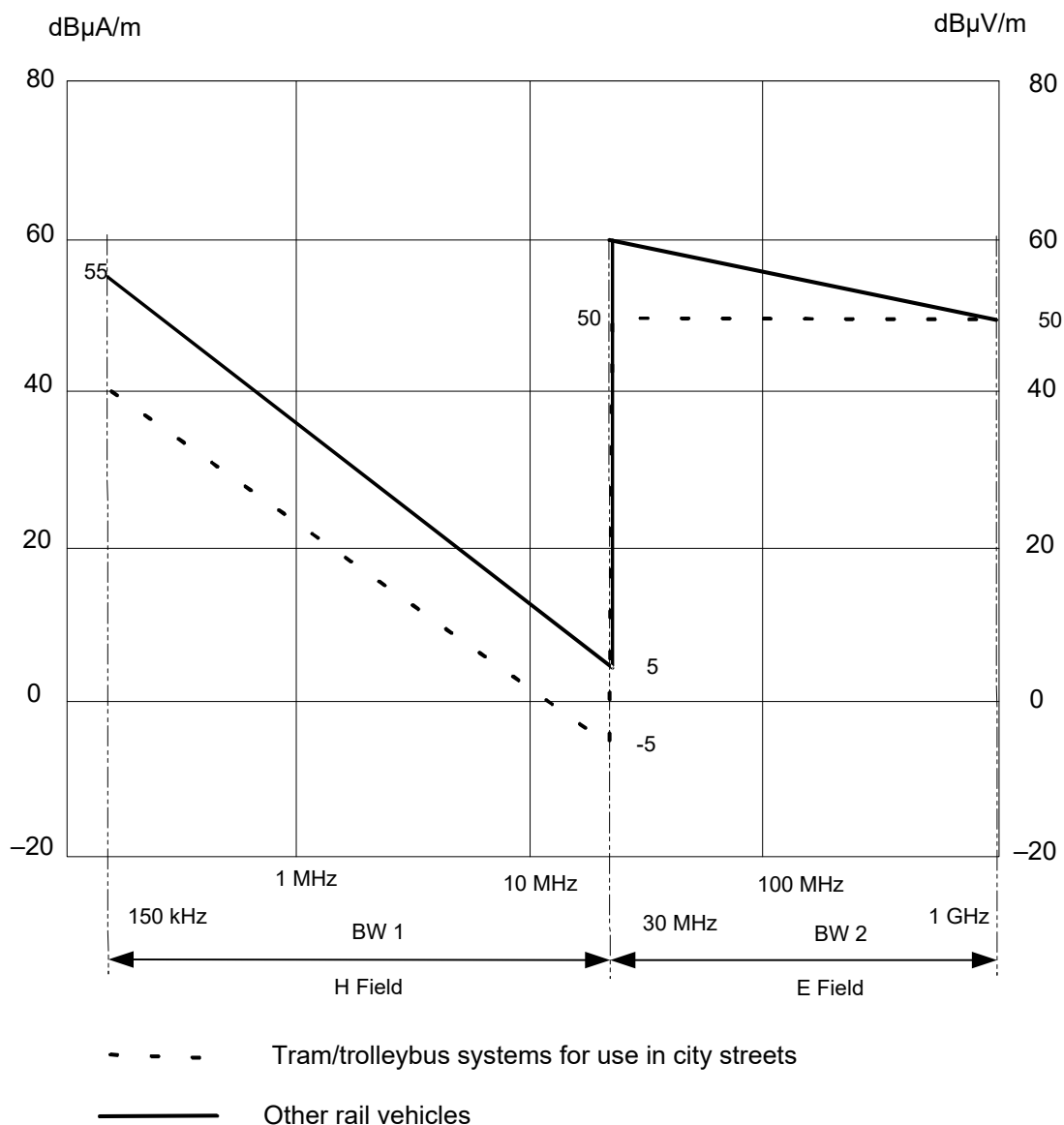
- the traction equipment ~~allows for operation whilst~~ can be operated while the vehicle is stationary;
- tests of electric braking are not required, if no different circuits are used in braking.

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

Any vehicles using onboard energy storage for traction shall use the test procedure and limits for slow moving test for the charging process.

NOTE Slow moving test procedure and limits are used for charging process (for traction energy storing devices) because it has a short duration with high energy transfer.

6.3.3 Emission limits



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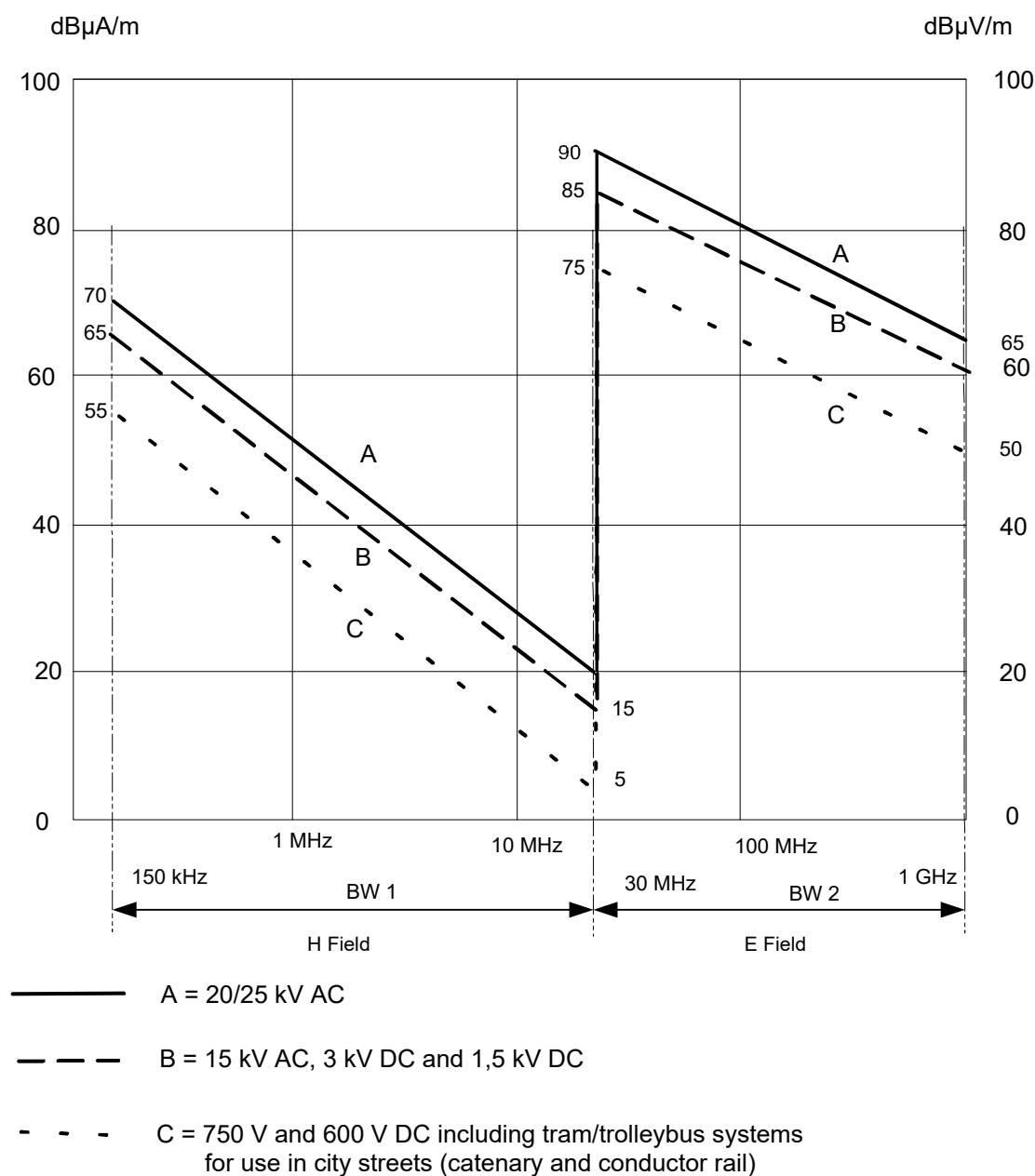
Figure 1 – Limits for stationary test (quasi-peak, 10 m)

NOTE The limits are defined as quasi-peak values and the bandwidths are those used in CISPR 16-1-1:

	Bandwidth
Frequencies up to 150 kHz	200 Hz
Frequencies from 150 kHz to 30 MHz	9 kHz (BW 1)
Frequencies above from 30 MHz to 1 GHz	120 kHz (BW 2)

NOTE All values are measured at a distance of 10 m from the centre of the track.

The emission limits are specified up to 1 GHz due to the fact that there are no significant sources of interference above 1 GHz and that emissions from microprocessor controlled equipment which may give rise to emissions at frequencies greater than 1 GHz are addressed by compliance with IEC 62236-3-2.



IEC

Figure 2 – Limits for slow moving test (peak, 10 m)

NOTE For details of test procedure, see Annex B.

NOTE All values are measured at a distance of 10 m from the centre of the track in peak values.

NOTE For diesel and diesel electric ~~locomotive~~ traction units and multiple units, the emission limits of Figure 1 ("other rail vehicles") and B in Figure 2 shall apply unless specific measures dictate otherwise (e.g. usage in lower voltage electrified lines).

The emission limits are specified up to 1 GHz due to the fact that there are no significant sources of interference above 1 GHz and that emissions from microprocessor controlled equipment which may give rise to emissions at frequencies greater than 1 GHz are addressed by compliance with IEC 62236-3-2.

~~NOTE—There are very few external radio services operating in the range 9 kHz to 150 kHz with which the railway can interfere. If it can be demonstrated that no compatibility problem exists, any emission level exceeding the relevant limits given in figure 1 and 2 may be acceptable.~~

Annex A (informative)

Interference on telecommunication lines

A.1 Harmonics in the traction current

A.1.1 General

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. Thus, it is the responsibility of the purchaser of the tractive stock in accordance with the rules of the infrastructure manager 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 this Annex. 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.

A.1.2 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:

- a) the structure of the telecom cables
 - 1) shielding, isolation to ground, balance of the cable;
- b) the characteristics of the telecom terminals
 - 1) susceptibility, input balance;
- c) the topology of the telecom network
 - 1) length of parallel sections of the telecom line to the tracks;
 - 2) the distance between tracks and telecom lines;
 - 3) the earth-resistivity;
- d) the topology of the railway network

- 1) single/double track;
- e) the type of power supply of the catenary
 - 1) AC / DC;
 - 2) substation ripple (DC rectifiers or AC 16,7 Hz static converters in some cases);
 - 3) type of catenary and feeder system (e.g. 1 × 25 kV or 2 × 25 kV);
 - 4) application of return conductors;
 - 5) single-end or double-end supply of the section under consideration;
- f) the density of train circulation;
- g) the current absorption and generation of harmonics of the tractive stock;
- h) 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 formula:

$$I_{\text{pso}} = \frac{1}{p_{800}} \sqrt{\sum (p_f I_f)^2}$$

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)~~ Directives ITU-T O.41 and ITU-T K.68.

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~~ is 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~~ are covered:

- a) Limits of I_{pso} under normal and under reduced performance conditions (one or more traction converters temporarily out of service).
- b) In the case of DC supply:

DC 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 DC 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~~ are relevant.

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

b) In the case of AC supply:

If the line voltage distortion has to be taken into consideration, the essential harmonics ~~shall have to~~ **be** specified. If special resonance conditions in the ~~catenary power supply~~ **line system** ~~shall be taken into account~~ **are relevant**, it ~~shall be~~ **is** 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~~ **is** 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 current is measured at the high voltage input of the vehicle and not on the ground side.**

The psophometric current ~~shall be~~ **is** 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 ~~should be~~ **is** measured in normal and in reduced operation mode (not all converters operating). The interpretation of the measurement results ~~should~~ **takes** 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.) ~~should be kept~~ **are** out of the evaluation.

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

A.5.1 Current of one tractive unit

A.5.1.1 General

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~~ **is** calculated according to the following rules:

A.5.1.2 DC systems

DC 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.

– DC systems with dominating rectifier ripple

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

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

- DC 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.5.1.3 AC systems

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

- AC 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.

- AC systems with 4 quadrant converters (4QC, pulse width modulated line converter)

$I_{\text{pso (total)}}$ ~~may be less than~~ $I_{\text{pso (one unit)}}$, if 4QC ~~operate in interlaced~~ depends on the ~~interlacing~~ mode ~~used~~ (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~~ disturbance generated in the range ~~9~~ 150 kHz to 1 GHz. It fulfils most of the IEC 62236-2 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 memorize 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~~ disturbance do not vary significantly during each scan.

The position, location, type and other features concerning the antennas are the same as described in IEC 62236-2:2018, Clause 5.

The measuring apparatus shall be in accordance with the CISPR 16-1-1:2015 requirements described in ~~4.2~~ Clause 5: "Peak measuring receivers for the frequency range 9 kHz to ~~1~~ 18 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: