

ERTMS/ETCS UNIT

**INTERFACES BETWEEN
CONTROL-COMMAND AND SIGNALLING TRACKSIDE
AND OTHER SUBSYSTEMS**

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1. INTRODUCTION

This document defines the interoperability requirements that are applicable at the interface between the Control-Command and Signalling Track-side and other subsystems (mainly, but not exclusively, rolling stock).

Since different types of trackside equipment originate different compatibility requirements, in this document traceability is provided, by mean of “justifications” explaining the source of each requirement.

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2. SCOPE

This specification is limited to requirements related to compatibility of train detection systems with other subsystems.

The possible effects of parameters on equipment other than train detection systems are not taken into account (e.g., rolling stock and operation are involved in respecting the requirement on maximum amount of sand, not to disturb track circuits operations, while the possible effects of sand on infrastructure elements like switches are not in the scope of this specification).

The requirements specified in this document have been identified on the basis of compatibility requirements of train detection systems, by reference to the train detection systems intended for use in interoperable lines, i.e.,

1. Axle counters (with electromagnetic wheel detectors)
2. Track circuits
3. Wheel detectors (e.g., for level crossing operations)
4. Vehicle detectors based on inductive loops

Train detection systems, which are part of the Control-Command and Signalling Track-side, shall be designed in such a way that they are able to detect a vehicle or consist under the conditions specified by the parameters in this specification.

In addition, these requirements apply to the relevant other subsystems as identified in the table below.

Table 1

| Parameter | Subsystem involved | | | | |
|---|--------------------|---|--------|----------------|----------------------------------|
| | CCS on-board | Rolling Stock | Energy | Infrastructure | Operation and Traffic Management |
| maximum axle distances | | X | | | X (train composition) |
| minimum axle distances | | X | | | X (train composition) |
| Distances between end of train and first axle | | X | | | X (train composition) |
| wheel geometry | | X | | | |
| maximum amount of sand | | X (technical characteristics of sanding devices) | | | X (use of sanding devices) |

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| Parameter | Subsystem involved | | | | |
|---|--|---------------|--------|----------------|---|
| | CCS on-board | Rolling Stock | Energy | Infrastructure | Operation and Traffic Management |
| sand characteristics | | X | | | |
| on-board flange lubrication | | X | | | X (activation of lubrication) |
| use of composite brake blocks | | X | | | |
| vehicle axle load and metal construction | | X | | | |
| use of shunting assisting devices (such devices are not required by CCS TSI, so no impact for subsystems compliant with TSIs; specific cases exist) | | | | | |
| impedance between wheels | | X | | | X (possibility of operational rules to control rust during operations) |
| Combination of rolling stock characteristics influencing shunting impedance | | | | | X |
| electromagnetic fields | X (emissions of Eurobalise antenna) | X | | | |
| vehicle impedance | | X | | | X (resulting impedance between rails and pantographs, in case of consists with more locomotives) |
| Traction current at fundamental power supply frequency | | | X | | |

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| Parameter | Subsystem involved | | | | |
|--|--------------------|--|--------|----------------|---|
| | CCS on-board | Rolling Stock | Energy | Infrastructure | Operation and Traffic Management |
| Conducted interference limits for traction current | | X | X | | X (number of trains running in the same power section) |
| use of magnetic/eddy current brakes | | X (technical characteristics of brakes) | | | X (operation of brakes) |

Unless otherwise indicated, the values of the parameters specified in this document apply for networks with the following nominal track gauges: 1435 mm, 1520 mm, 1524 mm, 1600 mm, and 1668 mm.

If, for a certain parameter, different values apply according to the track gauge, this is explicitly indicated in the corresponding section.

3. INTERFACE CHARACTERISTICS

3.1. VEHICLE DESIGN AND OPERATION

3.1.1. Definitions

For the definition of the longitudinal vehicle dimensions Fig. 1, (which shows an example for a three-axle twin-bogie vehicle), applies, where:

a_i = distance between following axles, where $i = 1, 2, 3, \dots, n-1$, where n is total number of axles of the vehicle

b_x = distance from first axle (b_1) or last axle (b_2) to the nearest end of the vehicle, i.e. nearest buffer/nose

L = total length of the vehicle

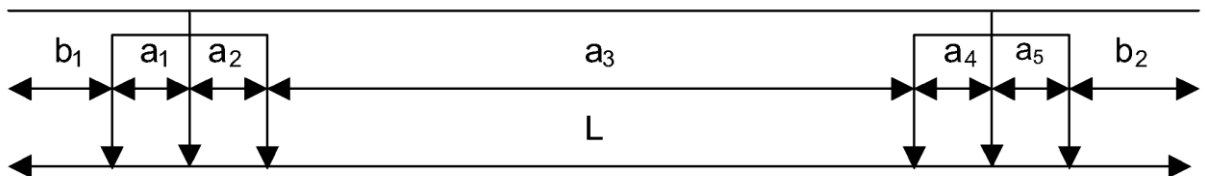


Figure 1: Longitudinal vehicle dimensions

If more vehicles are connected in a consist, the characteristics stated in the remainder of this section 3.1 and related to a_i apply to the relevant distance of the axles belonging to each vehicle individually, while the characteristics related to b_i only apply to the two ends of the complete consist.

For definition of wheel dimensions Fig. 2 applies, where:

D = wheel diameter

B_R = width of the rim

S_d = thickness of the flange measured at the line 10mm above the running tread as given in Fig. 2

S_h = height of the flange

Other dimensions in Fig. 2 are not relevant in this document.

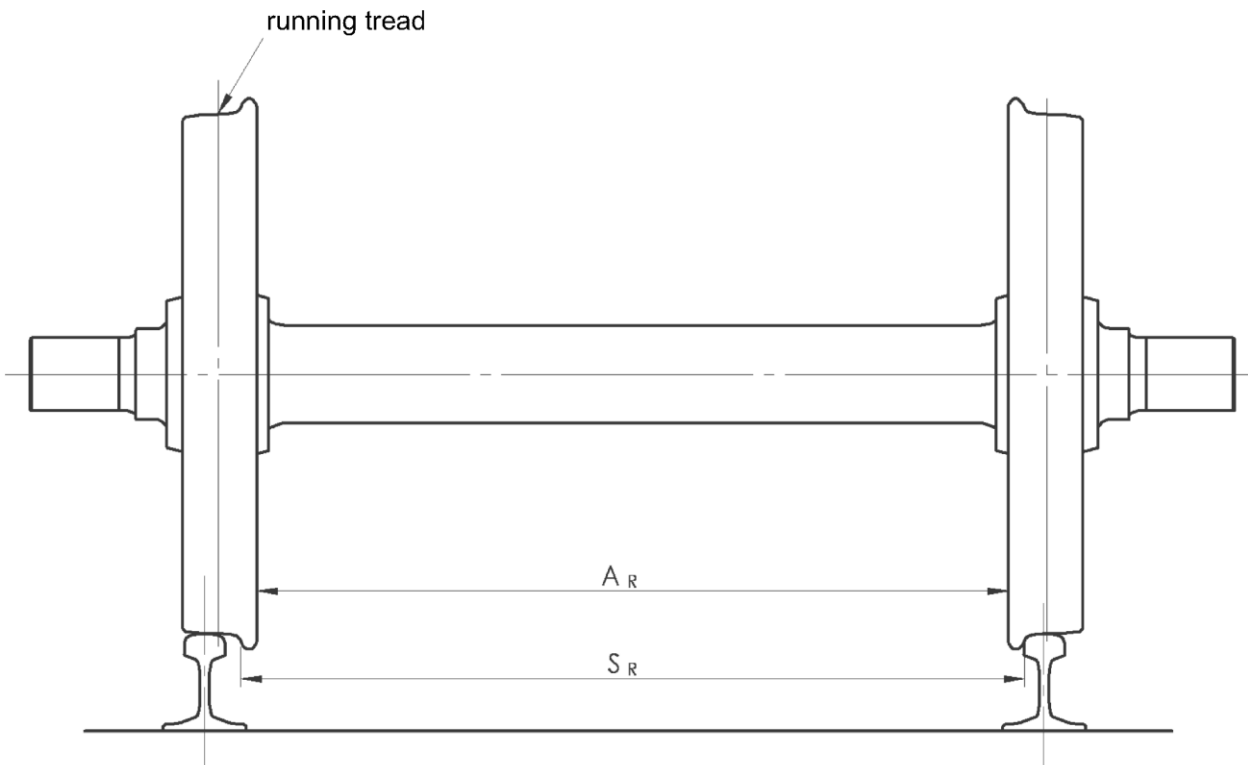
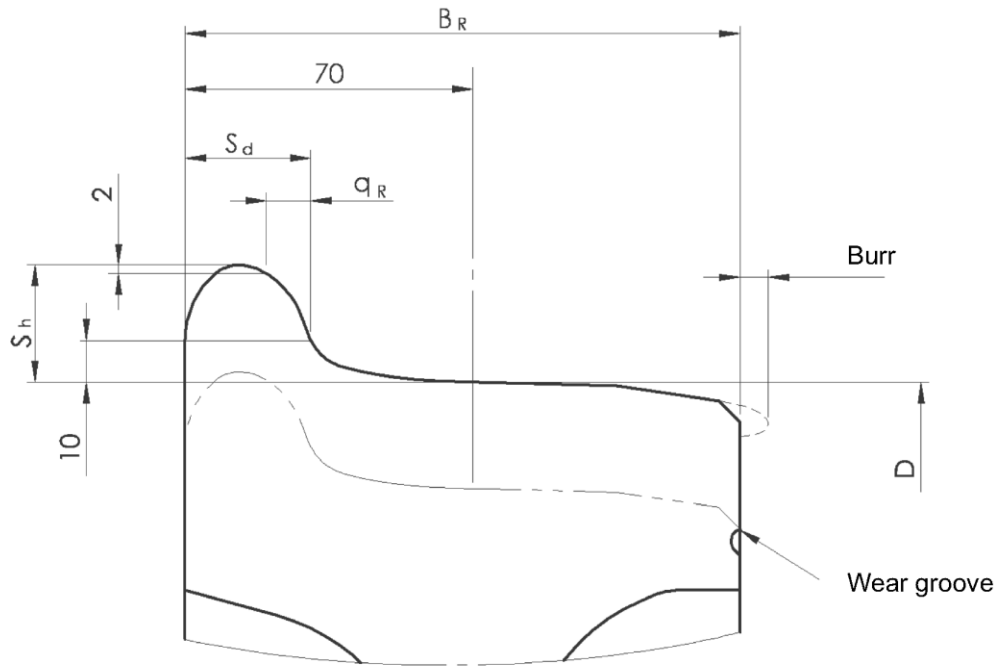


Figure 2: Wheel and wheelset dimensions

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The values quoted in the following paragraphs are absolute limit values including any measurement tolerances.

The term wheelset applies to any pair of opposite wheels, even those not connected by a common axle. Except where stated, wheelset assemblies are assumed to have continuous wheel centres and not have spoke wheels. Any references to wheel sets concern centre of wheels.

3.1.2. Axle distances

3.1.2.1. *Maximum axle distance*

Harmonised parameter for 1435 mm, 1600 mm and 1668 mm track gauge:
The distance a_i (Fig. 1) does not exceed 20 000 mm.

Harmonised parameter for 1520 mm and 1524 mm track gauge:
The distance a_i (Fig. 1) does not exceed 19 000 mm.

Justification:

This requirement is related to the minimum length of a signalling section, so that a vehicle or consist does not bridge it, making the train detection system report it as “unoccupied”.

3.1.2.2. *Minimum axle distance (1)*

Harmonised parameter for 1435 mm, 1600 mm and 1668 mm track gauge:

For the maximum speed v lower or equal to 350 km/h:

The distance a_i (Fig.1) is $a_i \geq v \times 7,2$ (where v is in km/h and distance a_i is in mm); this value applies jointly with the minimum wheels size (see 3.1.3.2).

Harmonised parameter for 1520 mm and 1524 mm track gauge:

For the maximum speed v lower or equal to 350 km/h:

The distance a_i (Fig.1) is $a_i \geq v \times 7,2$ (where v is in km/h and distance a_i is in mm) and $a_i \geq 500$ mm; this value applies jointly with the minimum wheels size (see 3.1.3.2).

Justification:

Axle counter systems have to be able to distinguish the detection of an axle by 2 subsequent counters with sufficient resolution; otherwise the result will be a count-error.

3.1.2.3. *Minimum axle distance (2)*

Harmonised parameter:

For the maximum speed v higher than 350 km/h, the distance a_i (Fig.1) is at least: [open point]

Justification:

Axle counter systems have to be able to distinguish the detection of an axle by 2 subsequent counters with sufficient resolution; otherwise the result will be a count-error.

3.1.2.4. *Minimum axle distance (3)*

Harmonised parameter:

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The distance between first and last axle $L - (b_1 + b_2)$ (Fig.1) is at least 3 000 mm

Justification:

The electrical joints between adjacent track circuits may have an area where the detection of an axle of a vehicle is not ensured.

3.1.2.5. *Distances between end of train and first axle on new High Speed lines*

Harmonised parameter:

The distance b_x (Fig. 1) does not exceed 5 000 mm.

Justification:

A train detection system shall be able to detect:

- the first axle before the nose of the train reaches a danger point ahead
- the last axle until the tail of the train has passed the danger point.

3.1.2.6. *Distances between end of train and first axle on other lines*

Harmonised parameter for 1435 mm, 1524 mm, 1600 mm and 1668 mm track gauge:
The distance b_x (Fig. 1) does not exceed 4 200 mm.

Harmonised parameter for 1520 mm track gauge:
The distance b_x (Fig. 1) does not exceed 3 500 mm

Justification:

A train detection system shall be able to detect:

- the first axle before the nose of the train reaches a danger point ahead
- the last axle until the tail of the train has passed the danger point.

3.1.3. Wheel geometry

3.1.3.1. *Minimum wheel rim width*

Harmonised parameter:

The dimension B_R (Fig. 2) is (this value is in line with what specified for geometrical characteristics of wheels in “Locomotives and Passenger rolling stock” and in the “Freight wagons” TSIs)

Wheel rim width as a function of the wheel diameter D

| Track gauge [mm] | Wheel diameter D [mm] | Wheel rim width B_R [mm] |
|------------------|------------------------|----------------------------|
| 1435 | $D \geq 330$ | 133 to 140 |
| 1520 | $D \geq 330$ | 126 to 146 |
| 1524 | $D \geq 400$ | 133 to 145 |
| 1600 | $690 \leq D \leq 1016$ | 137 to 139 |
| 1668 | $D \geq 330$ | 133 to 140 |

Justification:

The detection field of the axle counter is influenced by the wheel which passes. The rim width has to be big enough to influence the field sufficiently in order to ensure appropriate detection

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3.1.3.2. *Minimum wheel diameter*

Harmonised parameter:

For the maximum speed v , the dimension D (Fig. 2) is at least

| v [km/h] | D [mm] |
|--------------------|----------------------|
| $v \leq 100$ | 330 |
| $100 < v \leq 250$ | $150 + 1.8 \times v$ |
| $250 < v \leq 350$ | $50 + 2.2 \times v$ |
| $350 < v$ | [open point] |

For $v \leq 250$ km/h in the case of spoke wheels (spoke wheels of the design existing when this specification enters in force only), D is at least 600 mm

Justification:

The length of the influence of the detection field of the axle counter is related to the wheel diameter

3.1.3.3. *Minimum flange thickness*

Harmonised parameter:

The dimension S_d (Fig. 2) is (this value is in line with what specified for geometrical characteristics of wheels in “Locomotives and Passenger rolling stock” and in the “Freight wagons” TSIs)

Flange thickness as a function of the wheel diameter D

| Track gauge [mm] | Wheel diameter D [mm] | Flange thickness S_d [mm] |
|------------------|-------------------------|-----------------------------|
| 1435 | $330 \leq D \leq 760$ | 27.5 to 33 |
| | $760 \leq D \leq 840$ | 25.0 to 33 |
| | $D \geq 840$ | 22.0 to 33 |
| 1520 | $330 \leq D \leq 1220$ | 21 to 33 |
| 1524 | $400 \leq D \leq 760$ | 27.5 to 33 |
| | $760 \leq D \leq 840$ | 25.0 to 33 |
| | $D \geq 840$ | 22.0 to 33 |
| 1600 | $690 \leq D \leq 1016$ | 26 to 33 |
| 1668 | $330 \leq D \leq 840$ | 27.5 to 33 |
| | $D \geq 840$ | 22 to 33 |

Justification:

The detection field of the axle counter is influenced by the wheel which passes. The flange thickness has to be big enough to influence the field sufficiently to ensure appropriate detection.

3.1.3.4. *Flange height*

Harmonised parameter:

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The dimension S_h (Fig. 2) is (this value is in line with what specified for geometrical characteristics of wheels in “Locomotives and Passenger rolling stock” and in the “Freight wagons” TSIs)

Flange height as a function of the wheel diameter D

| Track gauge [mm] | Wheel diameter D [mm] | Flange height S_h [mm] |
|------------------|------------------------|--------------------------|
| 1435 | $330 \leq D \leq 630$ | 31.5 to 36 |
| | $630 \leq D \leq 760$ | 29.5 to 36 |
| | $D \geq 760$ | 27.5 to 36 |
| 1520 | $330 \leq D \leq 1220$ | 28 to 32 |
| 1524 | $400 \leq D \leq 630$ | 31.5 to 36 |
| | $630 \leq D \leq 760$ | 29.5 to 36 |
| | $D \geq 760$ | 27.5 to 36 |
| 1600 | $690 \leq D \leq 1016$ | 28 to 38 |
| 1668 | $330 \leq D \leq 630$ | 31.5 to 36 |
| | $630 \leq D \leq 760$ | 29.5 to 36 |
| | $D \geq 760$ | 27.5 to 36 |

Justification:

The detection field of the axle counter is influenced by the wheel which passes. The flange height has to be big enough to influence the field sufficiently to ensure appropriate detection

3.1.3.5. *Metal and inductive components-free space between wheels*

Harmonised parameter:

For freight wagons: only wheels and their parts (gearboxes, brake parts, sanding tube) or non-metallic and non-inductive components are permitted to be mounted in the sensitive area of Fig. 3.

For other vehicles: the possibility and conditions to install equipment in the sensitive zone of Fig. 3 are: [open point]

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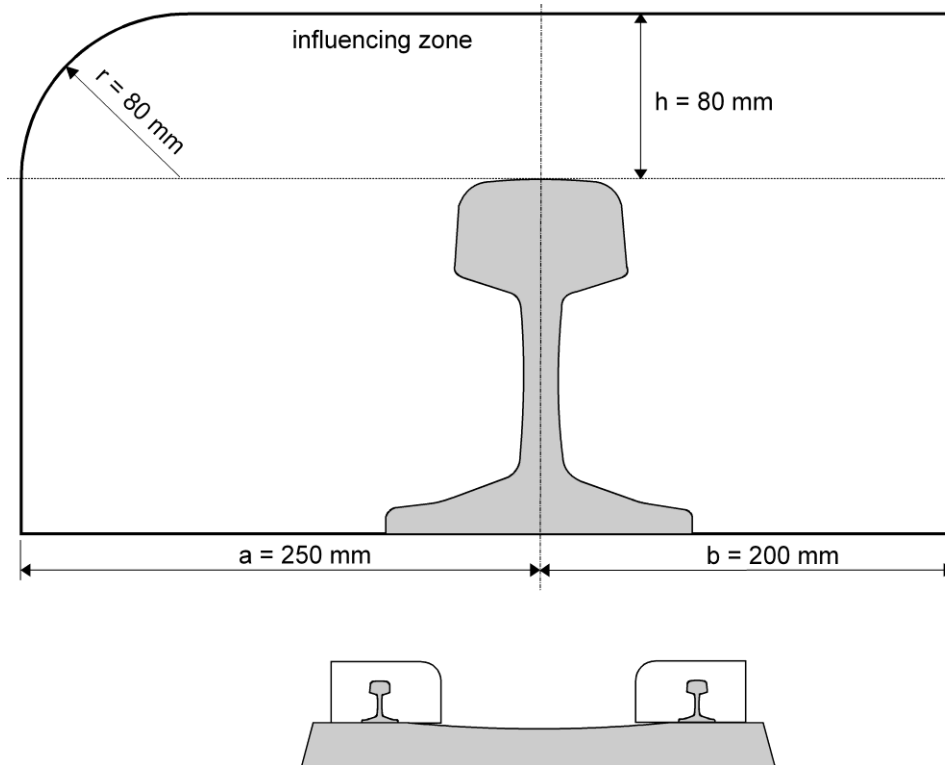


Fig. 3: Sensitive area

Justification:

The principle of axle counters is based on the distortion of an electromagnetic field. The distortion should occur only with the passage of the wheel and not with the passage of surrounding parts of rolling stock, like other ferromagnetic components or inductive coils.

Remark: The requirements of Fig. 3 can be respected by freight wagons; in case of locomotives it may be necessary to install equipment (e.g., brakes) in the area forbidden by Fig. 3.

3.1.3.6. Wheel material

Harmonised parameter:

The wheels have ferromagnetic characteristics and are electrically conducting.

Justification:

This characteristic is necessary to generate the distortion of the electromagnetic field of axle counters, to ensure appropriate detection.

3.1.4. Use of sanding equipment

3.1.4.1. Maximum amount of sand

Harmonised parameter for 1435 mm, 1524 mm, 1600 mm and 1668 mm track gauge: In case where an automatic sanding function is provided, it is possible for the driver to suspend its use.

The allowed amount of sand per sanding device within 30 s is:

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1. For speed $v < 140$ km/h; 400 g + 100 g
2. For speed $v > 140$ km/h; 650 g + 150 g

The number of active sanding devices does not exceed the following:

1. For multiple units with distributed sanding devices: first and last car and intermediate cars with a minimum of 7 intermediate axles, between two sanding devices that are not sanded. It is permissible to couple such multiple units and to operate all sanding devices at the coupled ends.
2. For loco-hauled trains
 - a. For emergency and full service braking: all available sanding devices
 - b. In all other cases: a maximum of 4 sanding devices per rail

Harmonised parameter for 1520 mm track gauge:
[open point]

This parameter shall be taken into account jointly with 3.1.4.2 (Sand Characteristics).

Justification:

Sand is applied to the tracks to improve braking and traction performance.

Sand can create an isolating layer between wheels and rails increasing the contact resistance, with risk of not detecting trains on tracks equipped with track circuits.

3.1.4.2. *Sand characteristics*

Harmonised parameter:

The characteristics of sand applied to the tracks are: [open point].

This parameter shall be taken into account jointly with 3.1.4.1 (Maximum amount of sand).

This parameter is to enable the margins related to contact resistance between wheels and rails to be taken into account for the use of track circuits.

Justification:

The composition of the sand which is used is relevant for the risk of not detecting trains on tracks equipped with track circuits.

3.1.5. **On-board flange lubrication**

Harmonised parameter:

If the vehicle is equipped with flange lubricators, it is possible to activate/deactivate them.

Justification:

Lubricant can create an isolating film between wheels and rails increasing the contact electrical resistance, with risk of not detecting trains on tracks equipped with track circuits.

3.1.6. **Use of composite brake blocks**

Harmonised parameter:

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The vehicles use brake blocks assessed for the effects on the contact electrical resistance between wheel and rail.

Justification:

Composite brake blocks can create an isolating film between wheels and rails increasing the contact electrical resistance, with risk of not detecting trains on tracks equipped with track circuits.

3.1.7. Vehicle axle load and metal construction

3.1.7.1. Vehicle axle load

Harmonised parameter for 1435 mm, 1524 mm, 1600 mm and 1668 mm track gauge:
The axle load is

1. at least 3,5 t for vehicles with more than 4 axles and wheel tread brakes,
2. at least 4 t for vehicles with 4 axles and wheel tread brakes,
3. at least 5 t for other vehicles (that is, vehicles that do not fall into categories 1 or 2).

Harmonised parameter for 1520 mm track gauge:
The axle load is [open point]

Justification:

A minimum axle load will activate pedals and treadles. Also, minimum axle load will have a beneficiary effect on the resistance between wheel and track, which is important for the operation of track circuits. Friction elements acting on the surface of wheels contribute to keep them clean and limit the increase of contact resistance.

3.1.7.2. Vehicle metal construction

Harmonised parameter for 1435 mm track gauge:

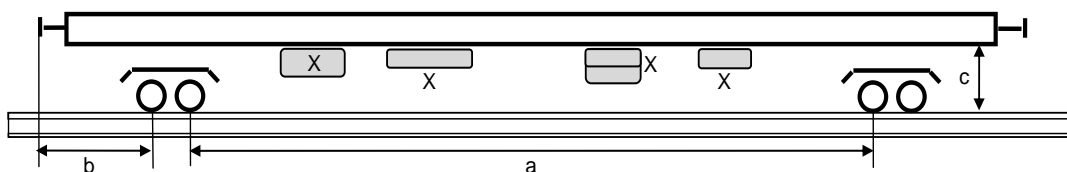
In the following, “length” refers to the direction in parallel to the track and “width” refers to the direction orthogonal to the track.

The description of this parameter is done with reference to the figure below:

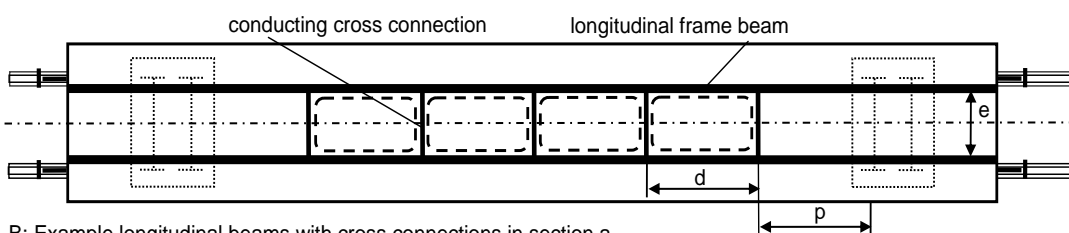
- a: section (distance) between the inner axles of two adjacent bogies or wheel sets
- b: section (distance) between the first (respectively the last) axle and the nearest end of the vehicle (excluding the coupling systems)
- c: distance between top of rail and vehicle floor (bottom side)
- d: distance between adjacent conducting cross connections / length of short circuit rings (electrically conducting loops) formed by frame beams and conducting cross connections
- e: distance of adjacent longitudinal frame beams
- f, g, h: dimensions of electrically connected conducting constituents (X)
- i, k: dimensions of short circuit rings (electrically conducting loops) formed by electrically connected conducting constituents (X)
- o: distance between adjacent short circuit rings

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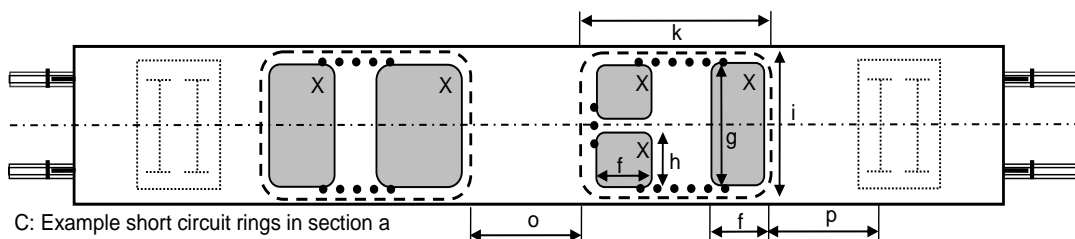
- p: distance between short circuit rings and adjacent wheel sets
X: conductive constituents mounted below vehicle floor



A: Defined distances and areas (the illustrated bogies with two axles are only an example; a bogie can consist of different numbers of axles)



B: Example longitudinal beams with cross connections in section a



C: Example short circuit rings in section a

Resulting short circuit ring (electrically conducting loop)

••••• Principle routing of the cables for the electrical connection of electrically conductive constituents

Fig. 4: Vehicle layouts

For the scope of this parameter, the vehicle is subdivided in different sections as shown in figure 4A: a central section (a), two outer sections (b) and the sections of the bogies or single wheel sets. The parameter is respected when the design of the vehicle is such that at least one of the conditions 1, 2 or 3 is fulfilled in section (a) and section (b) and condition 4 (or alternatively at least one of the conditions 1, 2 or 3) is fulfilled in the sections of bogies or single wheel sets (in case of vehicles without bogies):

1. The distance (c) between rail level and vehicle floor (bottom side) is less than 1.06 m and the vehicle has a metal floor over its full length (excluding the coupling systems) with a minimum width of 2 m and with a conductivity greater than $1 \text{ m}/(\Omega \text{ mm}^2)$.
2. The vehicle has constructive structures at least inside section (a) and (b) consisting of longitudinal frame beams symmetrically on both sides with a minimum distance (e) of 1.0 m. These are electrically connected with conducting cross connections in a distance (d) less than or equal to 3 m to form short circuit rings (electrically conducting loops) as illustrated in figure 4B, showing an example for section (a).

The electrical DC resistance of the resulting short circuit rings is lower than 1Ω .

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The distance (o) between adjacent short circuit rings does not exceed 3 m. The distance (p) between a short circuit ring and an adjacent wheel set of a bogie does not exceed 3 m, the distance to a single wheel set does not exceed 1.5 m.

The distance between rail level and short circuit rings on the bottom side of vehicle floor is less than 1.06 m.

3. The vehicle has electrically conducting constituents (X) mounted below the floor at least inside section (a) and (b). These are electrically connected to form short circuit rings (electrically conducting loops) as illustrated in figure 4C, showing an example for section (a). The dimensions of the constituents fulfil at least one of the following conditions:
- a) minimum width (g) of 2 m and minimum longitudinal length (f) of 1 m,
 - b) minimum width (h) of 1 m and minimum longitudinal length (f) of 1 m on both long sides of the vehicle.

The electrical connection is done in a way that short circuit rings with a length (k) equal or more than 2.5 m but less or equal than 3 m and a minimum width (i) of 2 m result. Figure 4C illustrates the principle routing of the cabling.

The conductivity of the conducting constituents is greater than $1 \text{ m}/(\Omega \text{ mm}^2)$. The electrical DC resistance of the resulting short circuit rings is lower than 1Ω .

The distance (o) between adjacent short circuit rings does not exceed 3 m. The distance (p) between a short circuit ring and an adjacent wheel set of a bogie does not exceed 3 m, the distance to a single wheel set does not exceed 1.5 m.

The distance between rail level and short circuit rings on the bottom side of vehicle floor is less than 1.06 m.

4. Bogies consist of metal parts with a conductivity greater than $1 \text{ m}/(\Omega \text{ mm}^2)$. Constructive supporting metal parts of a bogie frame are electrically connected with an electrical DC resistance lower than 1Ω . The distance between rail level and the bottom side of the bogie frame is less than 1.06 m.
Alternatively, if these requirements are not fulfilled at least condition 1, 2 or 3 shall be fulfilled in the section of the bogie.

Harmonised parameter for 1520 mm, 1524 mm, 1600 mm and 1668 mm track gauge:
No requirement on vehicle metal construction exist.

Justification:

This parameter specifies the requirements on the metal construction of a vehicle ensuring its detection by trackside inductive loops..

3.1.8. Use of shunt assisting devices

Harmonised parameter for 1435 mm, 1524 mm, 1600 mm and 1668 mm track gauge:
The use of shunting assisting devices is not required.

Harmonised parameter for 1520 mm track gauge:
[open point]

Justification:

Shunting assisting devices are not necessary for the operation of track circuits.

3.1.9. Impedance between wheels

Harmonised parameter:

The electrical resistance between the running surfaces of the opposite wheels of a wheelset does not exceed 0.05 Ohm, measured by a voltage between 1.8 VDC and 2.0 VDC (open circuit).

Justification:

A track circuit is only able to detect rolling stock if the impedance between rails does not exceed a certain value, given by the impedance of the opposite wheels of the wheelsets and the contact resistance at the wheel-rail surface.

The interface requirement given here is only related to the electrical resistance between the running surfaces of the opposite wheels of a wheelset.

Remark: operational rules may apply to ensure that a sufficiently low value of the contact resistance is maintained during service: see 3.1.4 (Use of sanding equipment), 3.1.5 (On board flange lubrication) and 3.1.6 (Use of composite brake blocks)

3.1.10. Combination of rolling stock characteristics influencing shunting impedance

Harmonised parameter:

The rules for combination of characteristics listed above (3.1.2 to 3.1.9) for vehicles or consists to ensure adequate operation with train detection systems are: [open point].

Remark: these are not additional conditions for the approval of rolling stock. These rules must be evaluated when checking the compatibility of a consist with the infrastructure, without the necessity of tests.

Justification:

These rules refer to possible conditions / limitations for the use of vehicles and consists on lines where track circuits are installed. Operation of track circuits relies on the contact resistance between wheels and rails that is influenced by the combination of several factors. The dynamic shunt behaviour differs from the static shunt behaviour. Even for vehicles or consists compliant with the single parameters defined in this specification, rules for the vehicles or consist may be necessary to cover this.

3.2. ELECTROMAGNETIC COMPATIBILITY

The requirements related to electromagnetic compatibility are expressed by means of “frequency management”, the purpose of which is to define the frequency ranges and the associated limits required for compatibility between rolling stock and track-side equipment.

3.2.1. Electromagnetic fields

3.2.1.1. Frequency management

The compatibility requirements specified in this section apply for 1435 mm, 1600 mm and 1668 mm track gauge network.

The compatibility requirements for 1520 mm and 1524 mm track gauge network are: [open point]

The frequency management defines three frequency bands:

1. 27 kHz – 52 kHz for band 1
2. 234 kHz – 363 kHz for band 2
3. 740 kHz – 1250 kHz for band 3

These requirements have been derived for the compatibility with axle counters. The requirements for electromagnetic fields related to compatibility of rolling stock with other kinds of train detection systems are: [open point]

The subsequent figures illustrate the compatibility limits for x, y and z directions.

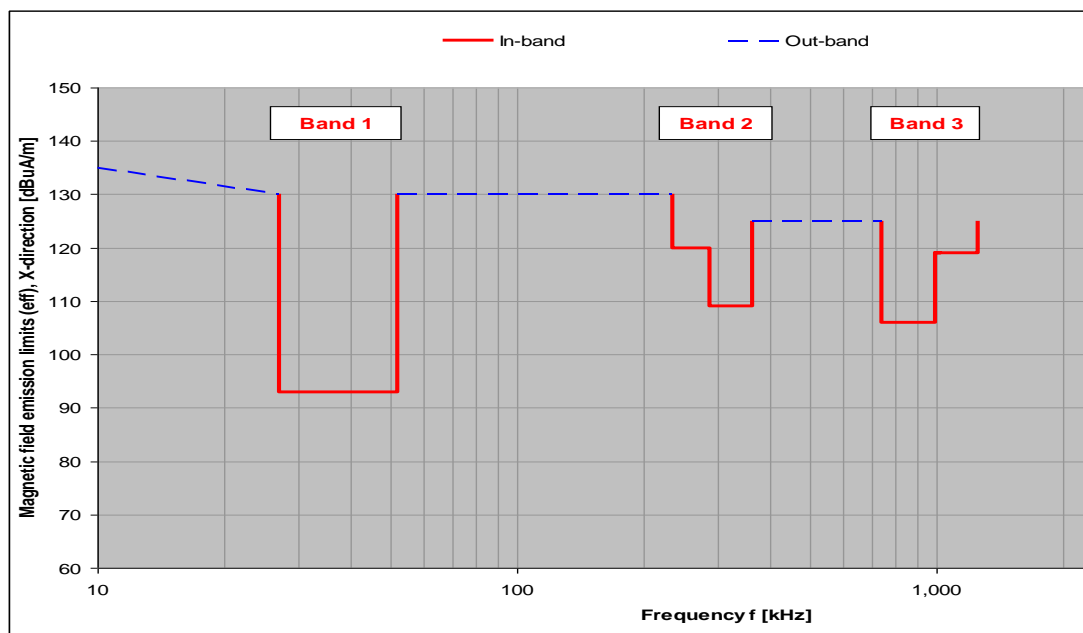


Figure 5: Compatibility requirements for X direction

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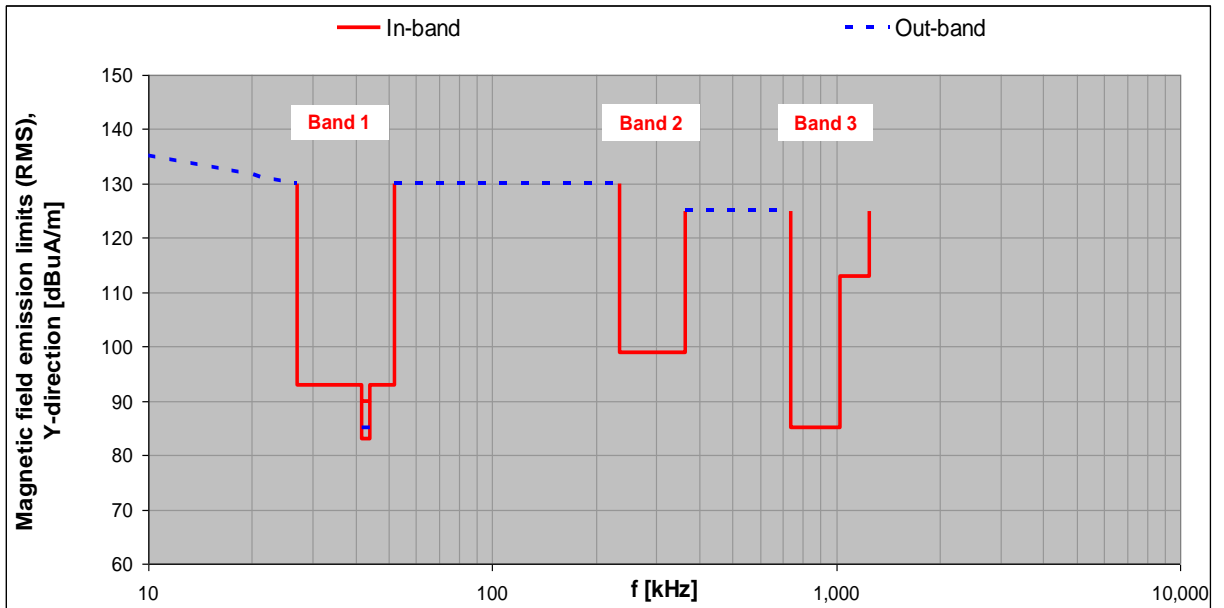


Figure 6: Compatibility requirements for Y direction

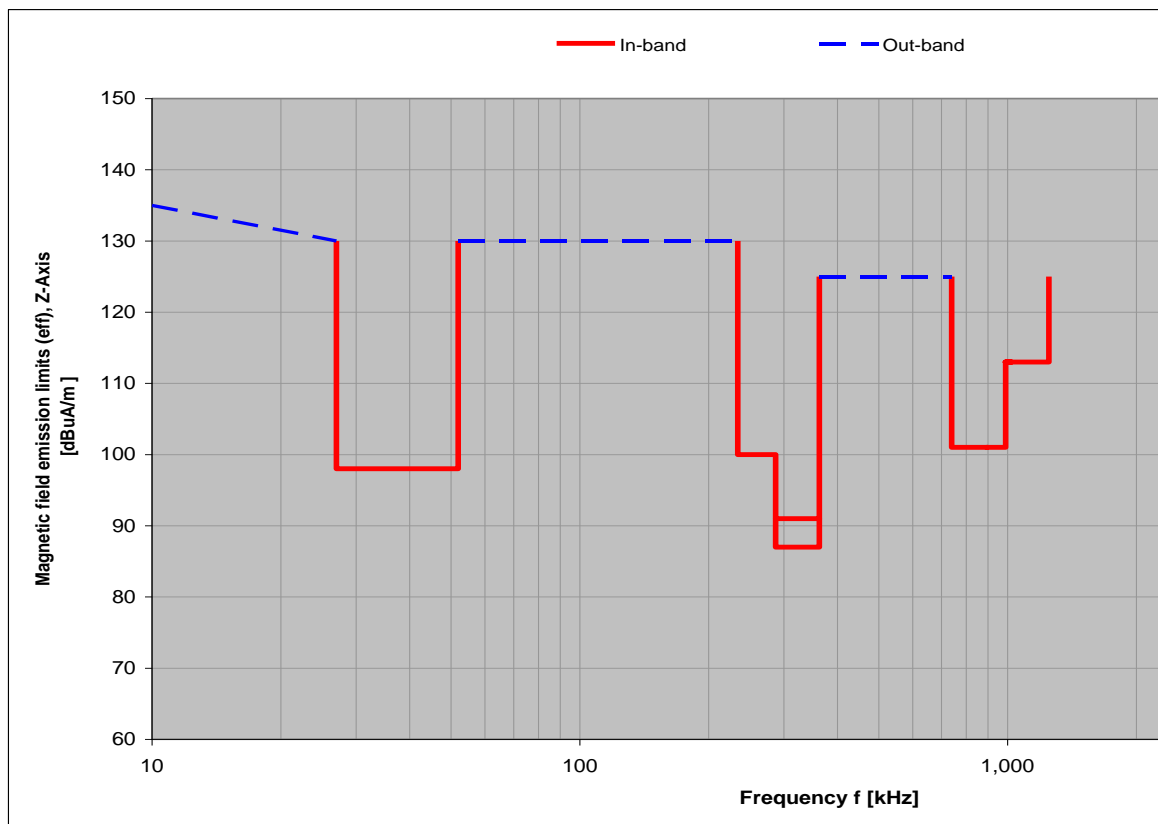


Figure 7: Compatibility requirements for Z direction

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Justification:

The magnetic fields generated by rolling stock can potentially interfere with the operation of train detection systems.

3.2.1.2. *Vehicle emission limits and evaluation parameters*

The limits and associated parameters for the evaluation of rolling stock emissions against the requirements in 3.2.1.1 are provided in the following table:

Table 2

| Band | Frequency range defined by the centre frequency [kHz] | Emission limit X Axis [dBµA/m] (RMS**) | Emission limit Y Axis [dBµA/m] (RMS**) | Emission limit Z Axis [dBµA/m] (RMS**) | Evaluation method | Filter order (butterworth) and 3 dB-bandwidth | Evaluation parameters |
|-------------|---|--|--|--|-------------------|---|---|
| Out of band | 10 to 27 | Linear decay from 135 to 130 | Linear decay from 135 to 130 | Linear decay from 135 to 130 | FFT | | Record time 1 ms, Hanning window, 50% overlap, max hold |
| Band 1 | 27 to 41.2 and 44.8 to 52 | 93 | 93 | 98 | BP | 4 th order 300 Hz | 20% overlap (3dB points) integration time: 1ms |
| Band 1 | 41.2 to 44.8 | 93 | 83*/90* | 98 | BP | 4 th order 300 Hz | 20% overlap (3dB points) integration time: 1ms |
| Band 1 | 41.8 to 44.2 | -- | 85 | -- | BP | 2 nd order 40 Hz*** | 20% overlap (3dB-points), integration time: 1ms |
| Out of band | 52 to 234 | 130 | 130 | 130 | FFT | | Record time 1ms, Hanning window, 50% overlap, max hold |
| Band 2 | 234 to 287 | 120 | 99 | 100 | BP | 4 th order; 7500 Hz | 20% overlap (3dB-points), integration time: 1.5 ms |
| Band 2 | 287 to 363 | 109 | 99 | 91 | BP | 4 th order; 7500 Hz | 20% overlap (3dB-points), integration time 1.5 ms |
| Band 2 | 287 to 363 | -- | -- | 87 | BP | 4 th order; 4000 Hz | 20% overlap (3dB-points), integration time: 1.5 ms |
| Out of band | 363 to 740 | 125 | 125 | 125 | FFT | | record time 1ms, Hanning window, 50% overlap, max hold |
| Band 3 | 740 to 1026 | 106 | 85 | 101 | BP | 4 th order; 10 kHz | 20% overlap (3dB-points), integration time: 1.5 ms |
| Band 3 | 1026 to 1250 | 119 | 113 | 113 | BP | 4 th order; 10 kHz | 20% overlap (3dB-points), integration time 1.5 ms |

* 90 dBµA/m for emissions under the train, defined by the distance between the middle of the first and the last axle of the train + 0.5m on both sides, independently of the radius of the wheels. See Figure 7 below.

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83 dB μ A/m for emissions measured before the first axle and after the last axle of the train has passed over the measurement sensor, see Figure 7 below.

** For in-band frequencies, the overlap for RMS calculations shall be at least 75%

FFT= Fast Fourier Transformation; BP= Band pass Filtering.

*** Prefiltering with a bandpass filter of 4th order and a 3 dB bandwidth of 1000 Hz is possible

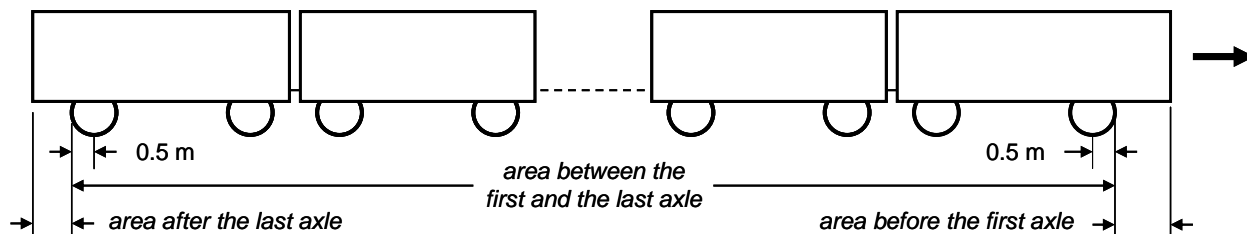


Figure 8

The uncertainty of the whole measurement chain shall be no more than +/- 1.75 dB of the defined magnetic field limit.

3.2.1.3. *Evaluation of exceedances of limits defined in table 2.*

In case there are exceedances of the limits specified in Table 2 and the minimum time interval between two exceedances is greater than the integration time T_{int} specified in Table 2, further evaluation can be done using shorter integration time as defined in table 3.

Table 3

| Frequency range | Field direction | Increasing of magnetic field limits for a reduced integration time of $0,5 \times T_{int}$ [dB] | Increasing of magnetic field limits for a reduced integration time of $0,25 \times T_{int}$ [dB] |
|------------------|-----------------|--|---|
| 27 to 52 kHz | X | 2 | 6 |
| 27 to 52 kHz | Y, Z | 6 | 12 |
| 234 to 287 kHz | X, Y, Z | 6 | 12 |
| 287 to 363 kHz | X, Y, Z | 3 | 6 |
| 740 to 1026 kHz | X, Y, Z | 6 | 12 |
| 1026 to 1260 kHz | X, Y, Z | 0 | 0 |

3.2.1.4. *Measurement specification*

The magnetic field limits specified in table 2 and 3 shall be measured using the antennas defined below.

A rectangular 3-dimensional magnetic loop antenna with a common centre point with the following geometrical dimensions shall be used:

1. 5 cm x 5 cm (X-direction)
2. 5 cm x 15 cm (Y- and Z- direction). The longest arm is always in X-direction.

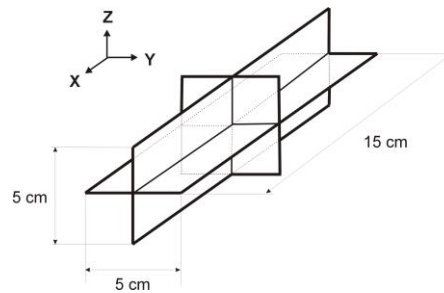


Figure 9: Loop antenna

The following table shall be used to define the mounting position of the measurement antennas for the frequency range considered. The centre point of the measurement antenna for the low frequency range (LFR) and high frequency range (HFR) shall have the following coordinates:

Table 4

| | Y1 [mm] | Z1 [mm] |
|---------------------------------|---------|---------|
| LFR (10 kHz to 100 kHz) | 98 | 73 |
| HFR (100 kHz to 1,3 MHz) | 94 | 68 |

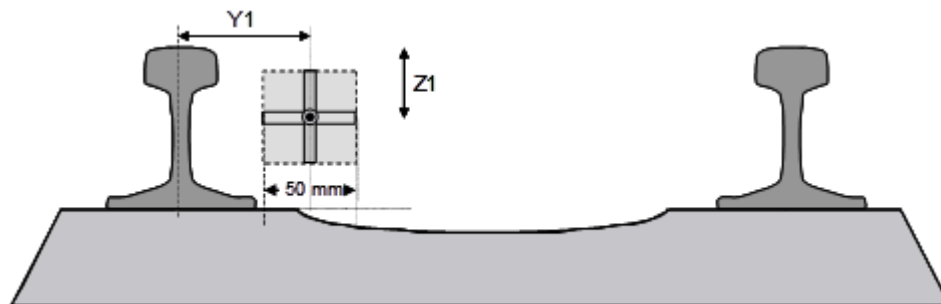


Figure 10: Position of the measurement antenna (internal between the rails)

The position of the measurement antenna shall be referenced with accuracy of +/- 2 mm.

3.2.2. Conducted interference

3.2.2.1. Vehicle impedance

The minimum impedance between pantograph and wheels of the consist is:
[open point]

Justification:

In train detection systems, to prevent interferences from harmonics generated in the traction system and to prevent (in case of track circuits) cross-over effect through the catenary system from one track to another, a sufficiently high impedance of the consist is necessary.

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3.2.2.2. *Traction current at fundamental power supply frequency*

There is no requirement applicable to rolling stock for a maximum harmonised value of the traction current at the fundamental power supply frequency.

Justification:

The traction current in the rails can potentially interfere with the operation of train detection systems.

The upper limit of this parameter is linked to the short circuit current of the traction power supply: this is a design issue of trackside subsystems and it is not directly associated with requirements for rolling stock.

Note: The requirements on harmonics of the traction current, which are applicable to rolling stock, are covered in the following points 3.2.2.3 to 3.2.2.7.

3.2.2.3. *25kV AC, 50Hz Electromagnetic interference limits for traction current*

The electromagnetic interference limits are:
[open point]

Justification: the harmonics in the traction current in the rails can potentially interfere with the operation of train detection systems.

3.2.2.4. *15kV AC, 16,7Hz Electromagnetic interference limits for traction current*

The electromagnetic interference limits are:
[open point]

Justification: the harmonics in the traction current in the rails can potentially interfere with the operation of train detection systems.

3.2.2.5. *3kV DC Electromagnetic interference limits for traction current*

The electromagnetic interference limits are:
[open point]

Justification: the harmonics in the traction current in the rails can potentially interfere with the operation of train detection systems.

3.2.2.6. *1,5kV DC Electromagnetic interference limits for traction current*

The electromagnetic interference limits are:
[open point]

Justification: the harmonics in the traction current in the rails can potentially interfere with the operation of train detection systems.

3.2.2.7. *750V DC Electromagnetic interference limits for traction current*

The electromagnetic interference limits are:
[open point]

Justification: the harmonics in the traction current in the rails can potentially interfere with the operation of train detection systems.

3.2.3. Use of magnetic / eddy current brakes

Harmonised parameter:

The use of magnetic and/or eddy current brakes is: [open point].

Justification:

The magnetic fields generated by those brakes can potentially influence axle counters.