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Guidance Note on Rolling Stock Electromagnetic Compatibility with Trackside CCS Subsystems

This document gives guidance on achieving rolling stock electromagnetic compatibility with control, command and signalling (CCS) subsystems, through supporting electromagnetic compatibility (EMC). It includes the methodology for the calculation of a transfer function for determining the impact of rolling stock line current on lineside copper cables as well as guidance on how to apply other EMC related standards from a rolling stock perspective.

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Synopsis

This document gives guidance on achieving rolling stock electromagnetic compatibility with control, command and signalling (CCS) subsystems, through supporting electromagnetic compatibility (EMC). It includes the methodology for the calculation of a transfer function for determining the impact of rolling stock line current on lineside copper cables as well as guidance on how to apply other EMC related standards from a rolling stock perspective.

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Part 1 Purpose and introduction

G1.1 Purpose

G1.1.1 This document gives guidance on electromagnetic compatibility (EMC) between rolling stock and some control, command and signalling (CCS) trackside subsystems. This document does not set out requirements and nor does it give guidance on touch potentials that may give rise to danger or compatibility between trains and electrification subsystems, other trains or neighbouring railways.

G1.2 Background

G1.2.1 Due to rolling stock drawing current from the electrification system, induced coupling occurs to lineside electronic systems that are sensitive to electromagnetic interference (EMI) and connected to copper cables.

G1.2.2 The BS EN 50121 series of standards sets out requirements for EMC limits to a range of systems and BS EN 50121-4:2016+A1:2019 specifically for emissions and immunity of the signalling and telecommunications apparatus; however, none of the standards in the series cover induced coupling and BS EN 50121-4:2016+A1:2019 is for CCS suppliers, rather than designers of rolling stock vehicles and equipment.

G1.2.3 Guidance is given in this document on electromagnetic compatibility (EMC) including on where inducedcoupling occurs between the current drawn by an electric train and control, command and signalling (CCS) trackside subsystems. It does not include guidance for EMC between multiple electric trains and a CCS trackside subsystem where the trains are operating in the same feeding section / area. Guidance for other methods of electromagnetic coupling, such as capacitive, conducted and radiated, are included in this guidance note, however the transfer function given in part two is for induced coupling only to lineside copper cables.

G1.3 User's responsibilities

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G1.4 Structure of this document

G1.4.1 Guidance is provided as a series of sequentially numbered clauses.

G1.5 Approval and authorisation of this document

G1.5.1 The content of this document will be approved by Rolling Stock Standards Committee on 13 June 2024 [proposed].

G1.5.2 This document will be authorised by RSSB on 14 August 2024 [proposed].

Part 2 Protection of telecommunication lines against harmful effects of rolling stock interference

G2.1 Introduction

Guidance

G 2.1.1 Copper cables adjacent to the GB mainline railway are used to transmit signals between two components of a system, including audio transmissions. EMI can affect analogue and frequency selective systems in different ways.

G 2.1.2 For analogue audio, interference typically manifests as noise, an unwanted sound that can be disruptive to the listener.

G 2.1.3 Frequency selective systems include digital systems as well as analogue systems which operate based on a specific received frequency and for these systems, as the individual elements of the signal may be considered to be 'on' or 'off', interference typically manifests at the receiver as either no signal being received, or a signal that is considered distorted or broken up.

G 2.1.4 Alternating current (ac) in the overhead contact line (OCL) and return circuit, or the ac content in the third rail and return circuit on direct current (dc) electrified railways, results in a voltage being induced into lineside copper cables. The voltage measured along a single cable from end-to-end is the longitudinal voltage, whereas the transverse voltage is the voltage between a pair of wires laid alongside the track.

G 2.1.5 Transverse voltages in lineside copper cables are present as a result of interference caused by systems adjacent to the cables. Rolling stock interference causes a proportion of this interference, but not all of it, and it is important to consider existing interference that may already exist on these lines due factors such as common mode, wire imbalance and shielding degradation.

G 2.1.6 A term for several induced voltages in a single wire, such as those described in *G 2.1.5*, is management voltages. Limits for each voltage can be set out and compliance with such voltages can therefore be established for each interfering system. ITU-T K.68 sets out requirements and guidance for operator responsibilities in the management of electromagnetic interference by power systems, including traction power, on telecommunication systems.

G 2.1.7 For a representative copper cable pair along a route where rolling stock is being introduced, interference can be measured at the lineside as longitudinal and transverse voltages; however, it is efficient for the train manufacturer to have an equivalent line current limit. This limit gives assurance that there is no significant interference with lineside copper cables and can be measured at the train rather than at the lineside. Establishing this limit is the objective of part two of this guidance note.

G 2.1.8 Induced interference from the current drawn by rolling stock to lineside cabling can be evaluated using a transfer function, which takes into account the known sensitivity of the lineside infrastructure system, hereafter referred to as the affected system. The transfer function given in this guidance note has been devised for the frequency range 50 Hz to 20 kHz.

G2.2 Methodology for the calculation of transfer functions between the train current and transverse voltage of lineside copper cables

G2.2.1 This section gives guidance on the methodology for the calculation of transfer functions between rolling stock line current and the transverse voltage of lineside copper cables using simulation software. Further guidance on the application of the methodology is given in *G2.4.2* and *G2.4.3*.

G2.2.2 The methodology for the transfer function given is applicable to cables connected to analogue and frequency selective systems.

G2.2.3 The methodology given in *G2.2.4* to *G2.2.6* can be implemented using various software packages. The method description, examples and results provided in this guidance note were performed using Finite Element Method Magnetics (FEMM) v4.2 software.

G2.2.4 Transverse voltage, $V_{transv}(f)$, is an induced voltage between a pair of affected wires that is caused by ac traction current in the OCL and return circuit.

G2.2.5 The transfer function, β(f), between $V_{transv}(f)$ and the train current, $I_{train}(f)$, can be modelled by injecting a fixed current value, such as 1 ampere, at respective frequencies into the relevant parts of electrification system conductors, for example the OCL and running rails. The induced voltage, $V_{long}(f)$, in each wire of a copper cable pair can be calculated or simulated during such scenarios over a fixed distance as long as the following assumptions are taken into account:

a) The copper cable pair and the respective electrification system conductors conducting the train current are installed in parallel over the whole calculated distance; and

b) The wires in the copper cable pair are also parallel to each other, with some separation between them, over the whole calculated distance.

G2.2.6 The induced voltage in each wire will be different due to the difference in magnetic flux over each of them that occurs as a result of them being different distances from the source. The absolute difference between the longitudinal voltage, $V_{long,}$ in wire 1 and wire 2 will determine the resulting transverse voltage given in *Equation One* and as shown in Figure *1*.

$$V_{transv}(f) = \left| V_{long\_w1}(f) - V_{long\_w2}(f) \right| \qquad \text{[Equation one]}$$

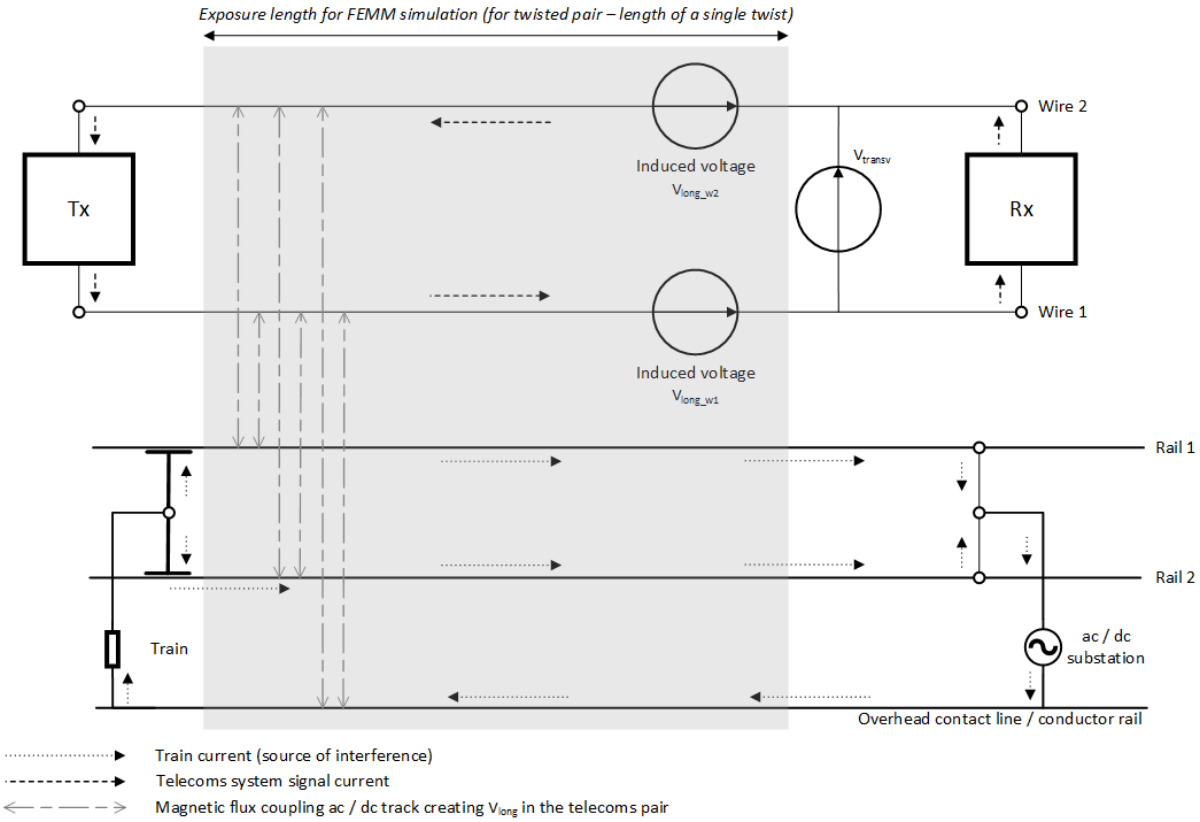

Figure 1: FEMM simulation exposure length

G2.2.7 For each of the modeled configurations,Table 1 and Table 2 give the magnitude and phase of the interference currents injected into each model type.

G2.2.8 In both ac and dc models:

a) No current was injected into the track 2 conductors as the effect of this would be low due to the greater distance to the copper cable pair; and
b) No current was injected into the copper cable pair as any induced voltage into the pair is due to the interference produced by the injected currents in the OCL and rails, as shown in Tables 1 and 2.

	OCL current	**Rail return current**		
Scenario	**Track 1 contact wire**	**Track 1 signal rail**	**Track 1 traction rail (Itr)**	**Booster/return conductor (Iret)**
25 kV ac electrification double track cross-section with single rail return	1 A, 0˚ phase	0 A	-1 A, 180˚ Phase	N/A
25 kV ac electrification double track cross-section with booster or earth return	1 A, 0˚ phase	0 A	-1 A, 180˚ Phase*	

* shared between the parallel conductors using equation $1/Z_{total} = 1/Z_{tr} + 1/Z_{ret}$, for example:

- Itr = -1 A/(1/(Z_{total} - 1/(Z_{ret})
- Iret = -1 A/((1/(Z_{total} - 1/(Z_{tr})

Table 1: Interference currents injected in the ac electrification models

	Conductor rail current	**Rail return current**	
Scenario	**Track 1 conductor rail**	**Track 1 rail 1 (Ir1)**	**Track 2 rail 2 (Ir2)**
750 V dc electrification double track cross-section	1 A, 0˚ phase	-1 A, 180˚ Phase**	

** shared between the parallel conductors using equation $1/R_{total} = 1/Z_{r1} + 1/Z_{r2}$, for example:

- Ir1 = -1 A/((1/(Z_{total} - 1/(Z_{r2})
- Ir2 = -1 A/(1/(Z_{total} - 1/(Z_{r1})

Table 2: Interference currents injected in the dc electrification model

G2.2.9 Dimensions that can be used for modeling a simulation exposure length are set out in:

a) GLRT1210 for OCL height;
b) GLRT1212 for dc conductor rail geometry;
c) Infrastructure (INF) National Technical Specification Notice (NTSN) for the nominal track gauge; and
d) INF NTSN specific case for the distance between track centres.

G2.2.10 A FEMM model of a typical 25 kV ac electrified double track cross-section is given in Figure 2 where only one steel rail was used as the return circuit for the required calculations. The copper OCL acted as the positive source, the affected wires were made of copper, and the earth and air were areas of the model transparent to magnetic flux with a relative permeability of one. The running rails and return conductor in this scenario are connected electrically in parallel, resulting in the return current being distributed between the return conductor and the running rails inversely proportional to the impedance of each of these conductors represented by the equation $1/Z_{total} = 1/Zr1+1/Zr2+1/Z_{return}$.

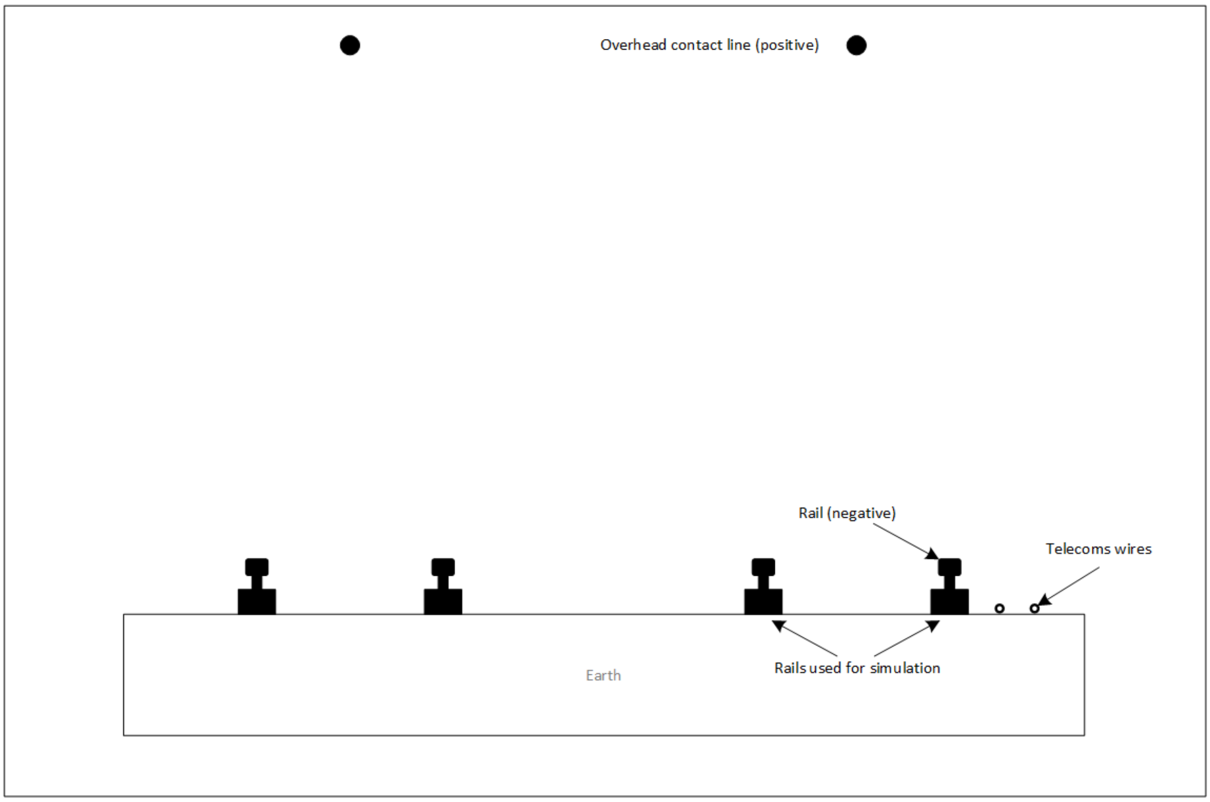

Figure 2: 25 kV ac electrification double track cross-section with single rail return

G2.2.11 An illustration of a classic 25 kV ac electrification double track section with a booster or earth return wire that was used for modelling is given in Figure 3.

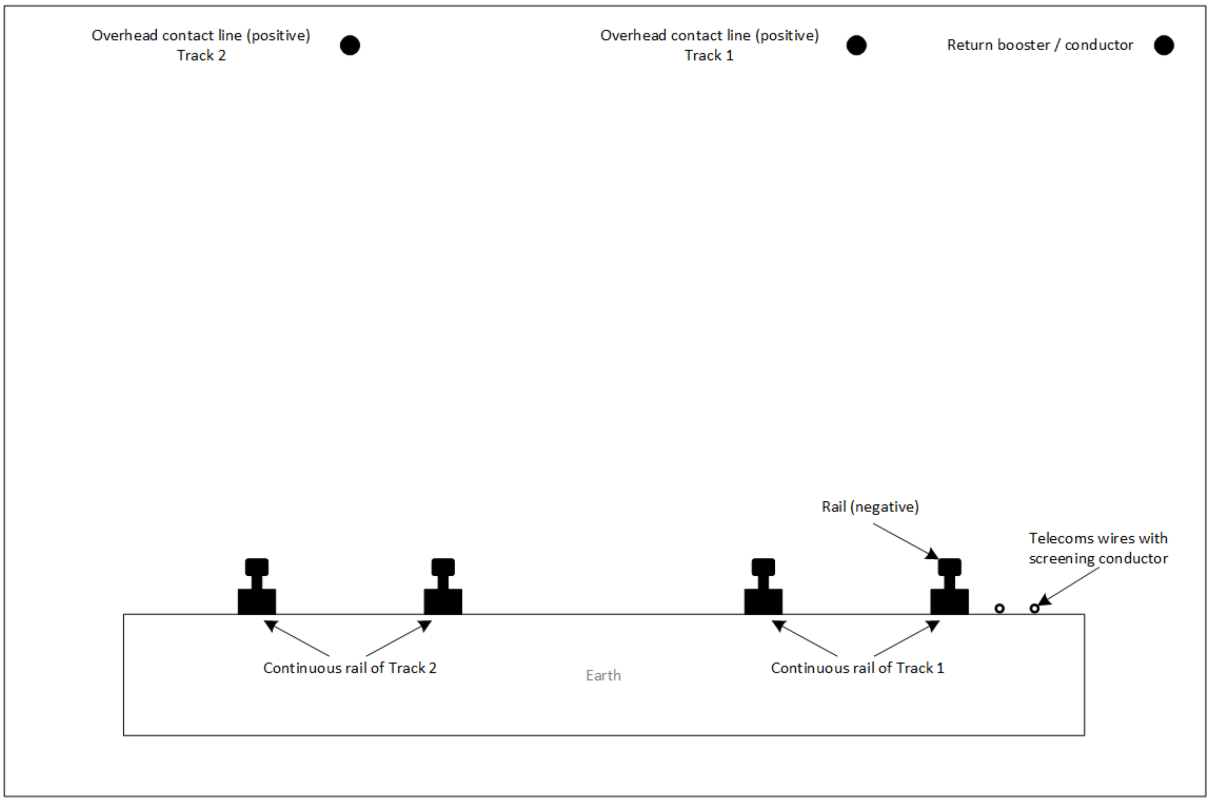

Figure 3: 25 kV ac electrification double track cross-section with booster or earth return

G2.2.12 For dc railways, the transfer function can be calculated using the same methodology as given in *G2.2.4* to *G2.2.6* but using a suitably adopted cross-section geometry of the electrification system conductors.

G2.2.13 An example of a two-track 750 V dc electrified double track cross-section is illustrated in Figure 4. Due to the conductor rail on dc railways being placed adjacent to the running rails, it is important to define where the copper cables are placed. The distance a copper cable pair needs to be from a dc conductor rail for reed frequency division multiplex (FDM) systems and for axle counter data links is set out in NR/SP/SIG/50011.

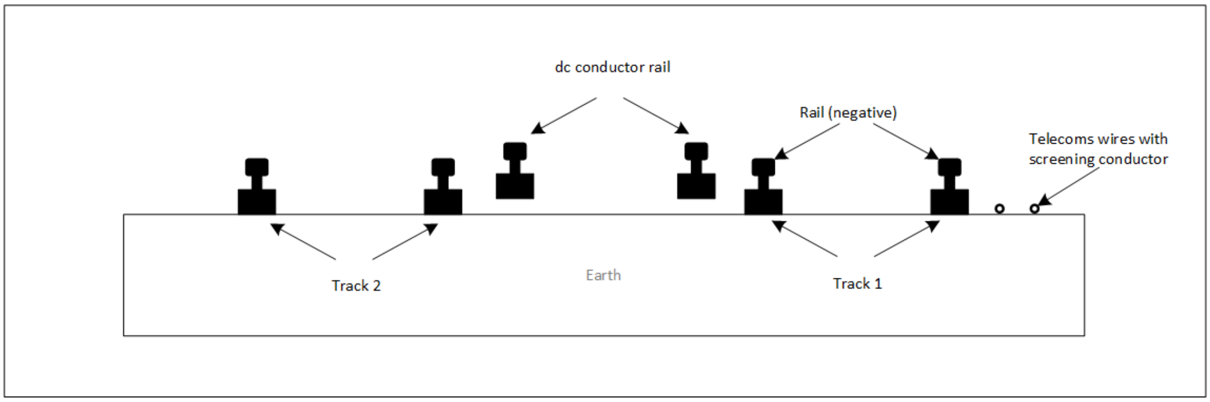

Figure 4: 750 V dc electrification double track cross-section

G2.3 Typical scenarios and transfer functions

Guidance

G 2.3.1 This section includes the scenarios used to model the outcome of the transfer function. The scenarios were chosen as they were considered to be representative of a range of cases on the GB mainline railway.

G 2.3.2 The measured data acquired as part of the project to validate the simulated transfer function results, as discussed in *G 2.3.10*, includes a deviation in the frequency response of the transverse voltage trend between two tests performed on 3 km and 10 km cable lengths. The divergence in the response occurs above 6.2 kHz, therefore above 6.2 kHz the transfer function may not be as accurate as expected.

G 2.3.3 Only a single cable twist was considered in the FEMM model as a full twist swaps the position of a copper cable pair and, theoretically, provides full cancellation. Longitudinal conversion loss (LCL) can be derived from measurements rather than calculated and is not a function of the interfering line current in an electrification system as LCL takes other factors into consideration. The objective of section two of this guidance note is to establish the transfer function between the interfering current and the induced or longitudinal voltage in the pair, meaning that LCL is not considered and outside of the sections scope.

G 2.3.4 The dimensions in Table *3* were used to perform the modelling given in this section for a classic 25 kV ac electrification double track section with a booster or earth wire as shown in Figure *3*. Additionally:

a) The scenarios included the rail return (RR) and booster return (BR) arrangements; and
b) The scenarios included a copper cable pair with and without parallel screening conductors (SC); and
c) Only twisted pair copper cables were used, with scenarios including one, ten and thirty metre complete twist lengths.

Feature	Dimension
Distance from OCL to the return / booster conductor	1 m
Distance from pair of trackside copper cables to closest running rail	1.3 m
Distance between the pair of copper cables	1 mm

Table 3: Dimension assumptions used for a classic 25 kV ac electrification double track section with a booster or earth wire

G 2.3.5 Systems with copper cable pairs that have shorter twist lengths are impacted less by induced coupling due to the close wire twists cancelling out interference.

G 2.3.6 Table 4 and Figure 5 give the FEMM calculated transfer functions V_{transv}/I_{train} (V/A) for cables with a maximum exposure length of one metre given by one complete twist.

Frequency (Hz)	FEMM_RR_SC	FEMM_BR_SC	FEMM_BR	FEMM_RR
50	2.98×10^{-7}	1.64×10^{-7}	8.62×10^{-8}	8.18×10^{-8}
100	6.67×10^{-7}	3.71×10^{-7}	1.02×10^{-7}	1.72×10^{-7}
200	1.36×10^{-6}	7.64×10^{-7}	1.51×10^{-7}	3.43×10^{-7}
300	2.05×10^{-6}	1.15×10^{-6}	2.08×10^{-7}	5.11×10^{-7}
400	2.73×10^{-6}	1.54×10^{-6}	2.68×10^{-7}	6.79×10^{-7}
500	3.41×10^{-6}	1.92×10^{-6}	3.29×10^{-7}	8.48×10^{-7}
1000	6.85×10^{-6}	3.86×10^{-6}	6.43×10^{-7}	1.70×10^{-6}
10000	6.95×10^{-5}	3.93×10^{-5}	6.36×10^{-6}	1.73×10^{-5}
20000	1.39×10^{-4}	7.85×10^{-5}	1.27×10^{-5}	3.46×10^{-5}

Table 4: Calculated FEMM transfer function values for cables with a complete twist of one metre (Volt-Ampere)

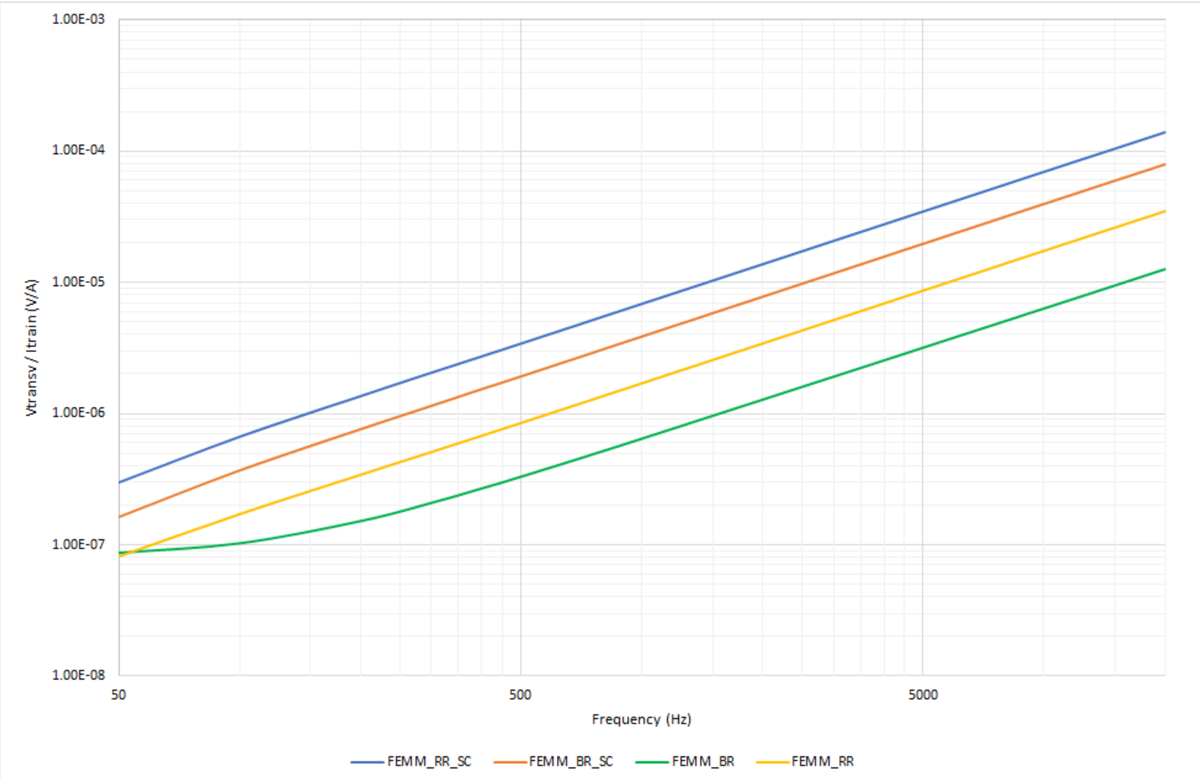

Figure 5: Graph of FEMM transfer function values for cables with a complete twist of one metre

G 2.3.7 The transfer functions that are given for ten and thirty metre twists are proportionate to the one metre case, for example, the values given in Table 4 are multiplied by ten to provide the values given in Table 5, and by thirty to give the values in Table 6. This means that the transfer function given is scalable to all twist lengths above one metre.

G 2.3.8 Table 5 and Figure 6 give the FEMM calculated transfer functions V/A for cables with a complete twist of ten metres.

Frequency (Hz)	FEMM_RR_SC	FEMM_BR_SC	FEMM_BR	FEMM_RR
50	2.98×10^{-6}	1.64×10^{-6}	8.62×10^{-7}	8.18×10^{-7}
100	6.67×10^{-6}	3.71×10^{-6}	1.02×10^{-6}	1.72×10^{-6}
200	1.36×10^{-5}	7.64×10^{-6}	1.51×10^{-6}	3.43×10^{-6}
300	2.05×10^{-5}	1.15×10^{-5}	2.08×10^{-6}	5.11×10^{-6}
400	2.73×10^{-5}	1.54×10^{-5}	2.68×10^{-6}	6.79×10^{-6}
500	3.41×10^{-5}	1.92×10^{-5}	3.29×10^{-6}	8.48×10^{-6}
1000	6.85×10^{-5}	3.86×10^{-5}	6.43×10^{-6}	1.70×10^{-5}
10000	6.95×10^{-4}	3.93×10^{-4}	6.36×10^{-5}	1.73×10^{-4}
20000	1.39×10^{-3}	7.85×10^{-4}	1.27×10^{-4}	3.46×10^{-4}

Table 5: Calculated FEMM transfer function values for cables with a complete twist of ten metres (Volt-Ampere)

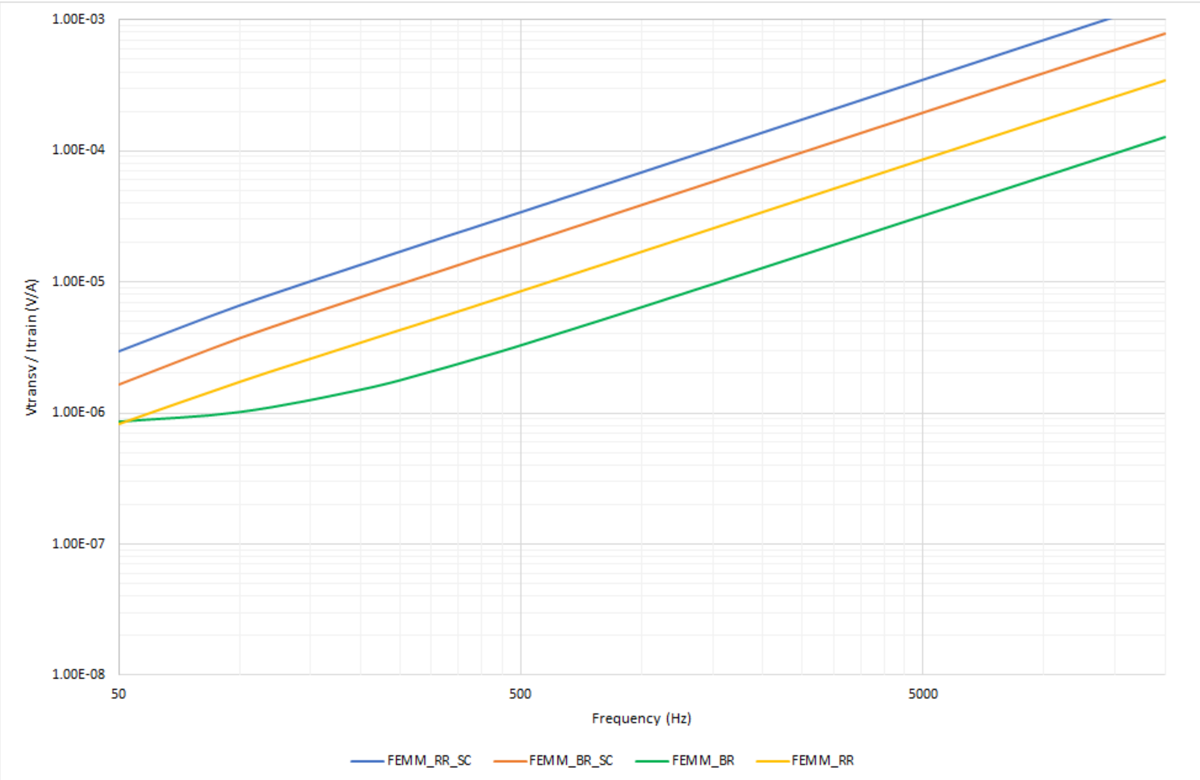

Figure 6: Graph of FEMM transfer function values for cables with a complete twist of ten metres

G 2.3.9 Table 6 and Figure 7 give the FEMM calculated transfer functions V/A for cables with a complete twist of thirty metres.

Frequency (Hz)	FEMM_RR_SC	FEMM_BR_SC	FEMM_BR	FEMM_RR
50	8.94×10^{-6}	4.92×10^{-6}	2.59×10^{-6}	2.45×10^{-6}
100	2.00×10^{-5}	1.11×10^{-5}	3.07×10^{-6}	5.15×10^{-6}
200	4.09×10^{-5}	2.29×10^{-5}	4.52×10^{-6}	1.03×10^{-5}
300	6.14×10^{-5}	3.45×10^{-5}	6.23×10^{-6}	1.53×10^{-5}
400	8.19×10^{-5}	4.61×10^{-5}	8.03×10^{-6}	2.04×10^{-5}
500	1.02×10^{-4}	5.77×10^{-5}	9.88×10^{-6}	2.54×10^{-5}
1000	2.05×10^{-4}	1.16×10^{-4}	1.93×10^{-5}	5.10×10^{-5}
10000	2.09×10^{-3}	1.18×10^{-3}	1.91×10^{-4}	5.18×10^{-4}
20000	4.18×10^{-3}	2.36×10^{-3}	3.80×10^{-4}	1.04×10^{-3}

Table 6: Calculated FEMM transfer function values for cables with a complete twist of thirty metres (Volt-Ampere)

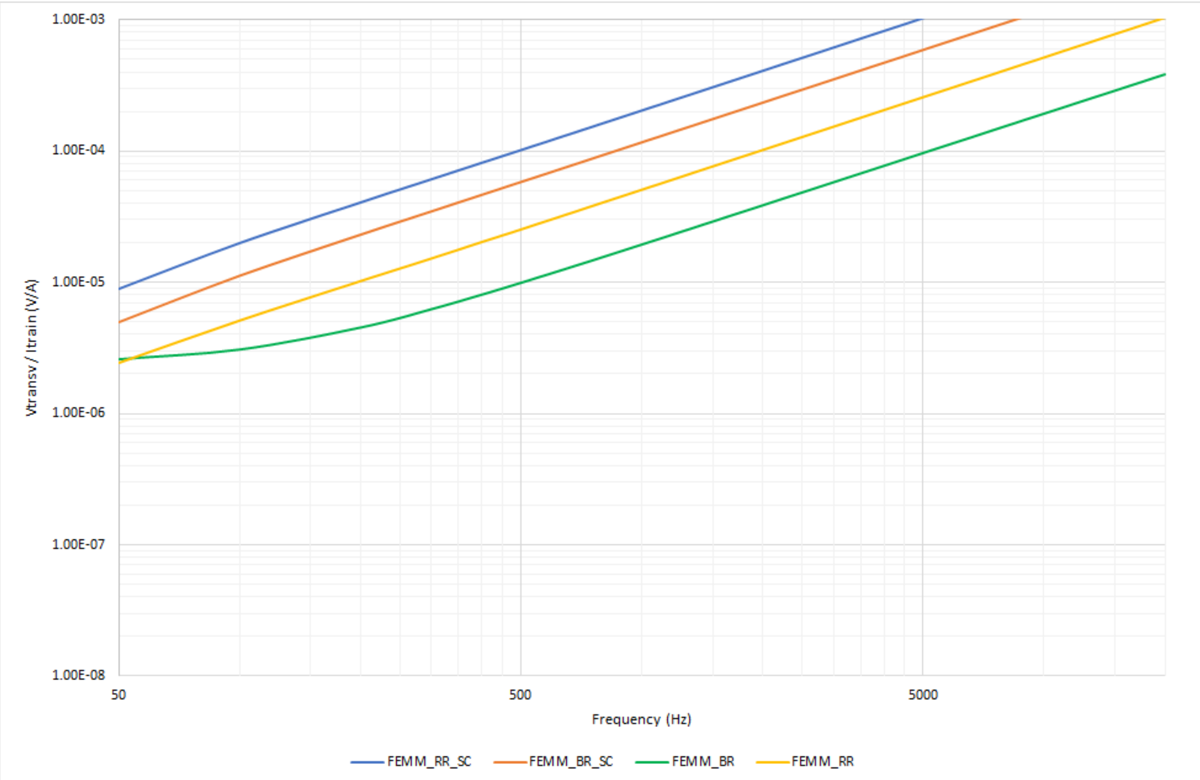

Figure 7: Graph of FEMM transfer function values for cables with a complete twist of thirty metres

G 2.3.10 The simulated transfer functions given in *G 2.3.6* to *G 2.3.9* were validated against measured data at various points of the GB mainline 25 kV ac electrified railway. The simulated transfer functions nearest to the measured data were:

a) FEMM_RR_SC with a thirty metre twist; and
b) FEMM_BR with a thirty metre twist.

The transfer functions for the other simulated RR and BR systems have not been validated against measured data as the results are scalable, as indicated in *G 2.3.7*. The analysis of the simulated transfer functions against measured data was presented to the electromagnetic compatibility sub-group (EMC SG) and the presentations are available on request from RSSB.

G 2.3.11 The typical scenarios presented in Tables *4* to *6* and the graphs in Figures *5* to *7* show a consistent pattern of the transfer functions against harmonic frequencies. The model used only considered induced coupling effects and therefore a shows a linear increase in the transfer function with frequency, with higher frequency interference currents producing proportionately higher voltages on lineside cables. In practice this will not necessarily be the case because other effects not included in the model, such as cable capacitance, will tend to reduce the transfer function as frequency rises.

G2.4 Application of the transfer function to different systems

G2.4.1 General

Guidance

G 2.4.1.1 Voice analogue telecommunications (telecoms), which on the railway is referred to as lineside telecoms, transmits voice in the broad frequency range of 50 Hz to 5 kHz, and the level of contribution of interference depends on the frequency.

G 2.4.1.2 The application of the psophometric weighting curve, which expresses sensitivity of a human ear to the frequency of sound, amplifies the interference in the broad frequency range and indicates whether the voice analogue telecoms system, which includes signal post and level crossing telephones, may become unintelligible should it be subjected to interference voltages that are either longitudinal or transverse.

G 2.4.1.3 Values for the psophometric weighting curve, Ps(f), are provided in Appendix *A*.

G 2.4.1.4 For higher frequencies, typically those at around 3 kHz and above, the application of the psophometric weighting curve to calculate interference values can result in interference being masked where the lineside copper cables are connected to frequency selective systems. The psophometric weighting curve is therfore not used to determine the effect of interference on frequency selective systems.

G 2.4.1.5 The objective of the application of the transfer function is to result in induced coupling into lineside copper cables from rolling stock that manifests as interference in a lineside system that is less than or equal to the susceptibility limits set out in NR/SP/TEL/50016 Figure 11.

G2.4.2 Analogue systems

G2.4.2.1 Application of the psophometric weighting curve

Guidance

G 2.4.2.1.1 The total emission on analogue telecommunication, V_{ta}, can be established using *Equation Two* where 1 mV is the analogue system weighted limit adopted for any analogue telecoms.

G 2.4.2.1.2 As the psophometric weighting factor has a wide frequency range, it is not possible to establish the frequency dependent train current limit for compliance with analogue telecoms systems; instead, equation two for a given train current harmonic profile is used to check if the train meets the 1 mV limit as set out NR/SP/TEL/50016.

G 2.4.2.1.3 *Equation Two* represents the effect on analogue telecoms for which a psophometric weighting curve can be used. α(f) can be calculated as the transfer function $\beta = V_t / I$ multiplied by the psophometric weighting curve, as given in *Equation Three*. The limit of 6 kHz is the limit of the psophometric weighting curve.

$$V_{ta} = \sqrt{\sum_{f=50}^{6000} [I_{train}(f)\alpha(f)]^2} < 1 \ mV \qquad \text{[Equation Two]}$$

Where:

$I_{train}(f)$ = train current at frequency f; and

α(f) = weighted factor for train current and frequency f

$$\alpha(f) = \beta(f) \times Ps(f) \qquad \text{[Equation Three]}$$

Where:

β(f) = the transfer function between $V_{transv}(f)$,and $I_{train}(f)$, expressed as $\beta(f) = V_{transv}(f) / I_{train}(f)$

G 2.4.2.1.4 V_{transv} is the transverse voltage on the analogue telecoms pair induced from the train current, I_{train}.

G 2.4.2.1.5 The transfer function for analogue telecoms, β(f), can be established by modelling a section of the railway.

G 2.4.2.1.6 Exceeding psophometric current values at any frequency, which are limits for whether a vehicle is compatible with analogue CCS trackside subsystems, can result in vehicles failing type-tests.

G2.4.3 Frequency selective systems

G2.4.3.1 V_t susceptibility limits

Guidance

G 2.4.3.1.1 Susceptibility limits of CCS trackside subsystems are typically calculated at their receivers and therefore may not take into consideration the effect of transverse voltages that exist in lineside copper cables that connect them and the impact these can have on system operation.

G 2.4.3.1.2 Line current limits for rolling stock EMC with CCS trackside subsystems are well documented; however, there are few known transverse voltage limits for copper cabling associated with CCS trackside subsystems.

G2.4.3.2 Train current calculation for EMC with different arrangements of copper cables

Guidance

G 2.4.3.2.1 Using the transfer function $\beta = V_t/I$, and knowing the susceptibility limit of the system, $V_{tlim}(f)$, the train current limit curve, $I_{tlim}(f)$, for a frequency selective system can be established, as given by *Equation Four*.

$$I_{tlim}(f) = V_{tlim}(f) / \beta(f)$$ [Equation Four]

G 2.4.3.2.2 If the susceptibility limit of the system is unknown, it can be established by multiplying $I_{train}(f)$ and β, as given by *Equation Five*.

$$V_{tlim}(f) = I_{train}(f) \times \beta(f)$$ [Equation Five]

G 2.4.3.2.3 If sensitivity in terms of the transverse voltage limits, $V_{tsel}(f)$, across the pair at the operating frequency band of the frequency selective system is known, to establish the train current limit for EMC with frequency selective systems, the approach is different to analogue systems given in *G 2.4.2.1.3*, as given in *Equation Six*.

$$I_{train}(f) = V_{tsel}(f) / \beta(f)$$ [Equation Six]

G 2.4.3.2.4 Unlike analogue telecoms systems, frequency selective systems:

a) Are only affected by specific frequencies or a frequency range at which the receiver operates; and
b) Have specific $V_{tlim}(f)$ values at respective frequency bands which are established for each system.

G 2.4.3.2.5 The resultant transverse voltage across the frequency selective system pair, $V_{tfs}(f)$, is given in *Equation Seven*.

$$V_{tfs}(f) = \beta(f) \times I_{train}(f)$$ [Equation Seven]

G 2.4.3.2.6 The transfer function for the frequency selective system, β(f), can be established by using the modelling of the section of the railway in the same way as is performed for analogue systems.

G2.4.3.3 Train current calculation for EMC with certain frequency selective systems' copper cables

G2.4.3.3.1 Solid state interlocking (SSI)

Guidance

G 2.4.3.3.1.1 Solid state interlocking (SSI) trackside data links (TDL) use a spectrum centred on 10 kHz, which is broadened by normal messages resulting in an operating frequency range of 1 kHz to 20 kHz. Interference by induced currents to SSI TDLs can be determined by measuring the unweighted traction current. Although SSI TDLs have features that mitigate traction interference, such as complex messaging and two levels of coding, the system remains susceptible; however, the limits are undefined as the system typically fails as a result of numerous message send and receive errors rather than due to voltage limits.

G 2.4.3.3.1.2 BS EN 50121-3-1:2017+A1:2019 sets out requirements and guidance for determining interference at frequencies that overlap with the SSI operating range; however, the method of electromagnetic coupling in BS EN 50121-3-1:2017+A1:2019 standard includes conductive, capacitive or radiated and does not consider inductive coupling which is covered in part 2 of this guidance note.

G2.4.3.3.2 Reed frequency division multiplexing (FDM)

Guidance

G 2.4.3.3.2.1 FDM is a method where the total available bandwidth of a communication medium is split into separate frequency channels with each channel carrying its own signal. The use of FDM permits the exploitation of a single communication medium, such as a copper cable, to send multiple signals with different information.

G 2.4.3.3.2.2 An independent transmitter generates an ac signal at the frequency allocated to each channel and an individual receiver detects the frequency for each channel. Discrete channels are typically chosen within a range to avoid supply frequency harmonics.

G 2.4.3.3.2.3 Two types of reed FDM systems are in use in GB - vital and non-vital. Vital reed FDM systems are used for the control and indication of safety critical functions between interlocking and trackside signalling equipment and typically use a twisted copper cable pair as a communication medium. Non-vital reed FDM systems have a similar design to the vital systems but can include equipment which does not fail safe and may also use multicore cabling.

G 2.4.3.3.2.4 The transmitter and receiver in reed FDM systems consist of a reed filter and an amplifier. The reed filter is a high-q band-pass filter, which passes only the frequency allocated to each channel and excludes all others with a nominal bandwidth of ± 0.5 Hz. The selectivity of the reed filters is such that the system can be operated with frequencies as close as 4 Hz, permitting the accommodation of a large number of channels within a small range of frequencies.

G 2.4.3.3.2.5 For reed FDM remote control systems, the frequencies used for transmission are broadly in the range from 383 - 880 Hz. NR/GN/SIG/50015 sets out that reed FDM remote control systems are susceptible to transverse voltages at the transmission frequency of:

a) 112 mV, giving 22.4 mV at the reed frequencies for vital reed FDM systems; and
b) 63 mV, giving 37.8 mV at the reed frequencies for non-vital reed systems.

Part 3 Guidance on EMC to other CCS trackside subsystems

G3.1 General

Guidance

G 3.1.1 The guidance given in this section relates to interference that is typically emitted from traction power converters as noise which varies continuously due to factors such as speed, position and acceleration; however it is understood that there are conditions that occur on the network which can result in transients. These transients result in electromagnetic interference with CCS trackside subsystems and can happen due to the configuration of infrastructure and electrification subsystems surrounding the rolling stock. Although this phenomenon is rare, it can result in the malfunction of CCS trackside subsystems, but is not considered in this guidance note due to a lack of current information on the subject.

G 3.1.2 Analytical and measurement methods that have produced the limits quoted in most of the existing references and standards use electrical theory and signal theory in the frequency domain which is inherently representative of continuous, steady-state interference.

G 3.1.3 The sources of information given as guidance in this section were typically developed to support safety assessments so that it could be demonstrated that rolling stock vehicles would not cause maloperation of CCS trackside subsystems.

G 3.1.4 Some CCS systems, including track circuits, fail to a safe state, often referred to as a 'right-side' failure, but which can still affect the overall performance of the railway.

G 3.1.5 CCS systems can be sensitive to EMI in out-of-band frequency ranges where susceptibility limits are unknown.

G 3.1.6 NR/GN/SIG/50014 gives additional guidance on methodologies for demonstrating compatibility with lineside equipment that is not included in this standard.

G3.2 Compatibility with track circuits

Guidance

G 3.2.1 Single rail track circuits are designed for traction return currents to be passed through one of the running rails and are not fitted with an impedance bond.

G 3.2.2 Double rail track circuits are designed for traction return currents to be passed through both running rails.

G3.2.1 Track circuits found on ac railways

G3.2.1.1 dc (ac immune) track circuits

Guidance

G 3.2.1.1.1 dc (ac immune) track circuits operate by applying power at one end of a section which is transmitted to the dc track relay at the other end of the section. They are used in both single and double rail configuration; however, on ac lines only single rail configurations are used. Insulated rail joints (IRJs) are located at each end of the section to electrically isolate them from the next.

G 3.2.1.1.2 For train set compatibility, RIS-0725-CCS issue 1.1, part 3.1, gives guidance on the accepted limits for the susceptibility of dc (ac immune) track circuits for different equipment arrangements.

G3.2.1.2 Single rail reed track circuits for use on the ac railway

Guidance

G 3.2.1.2.1 Single rail reed track circuits on the ac railway are single frequency track circuits with the operating frequencies; 363 Hz, 366 Hz, 369 Hz, 372 Hz, 375 Hz, 378 Hz, 381 Hz, 384 Hz, 408 Hz, 417 Hz and 423 Hz, typically referred to by channel numbers f211 to f221.

G 3.2.1.2.2 Single rail reed track circuits on the ac railway comprises the following components:

a) Track filter;
b) Electromechanical filter (reed filter);
c) Amplifier; and
d) Follower relay.

G 3.2.1.2.3 For train set compatibility, RIS-0725-CCS issue 1.1, part 3.2, gives guidance on the accepted limits for the susceptibility of single rail reed track circuits.

G3.2.1.3 EBI Track 200 track circuits (ac lines)

Guidance

G 3.2.1.3.1 EBI Track 200 track circuits, historically referred to as TI-21 track circuits, are jointless and operate in the audio frequency band.

G 3.2.1.3.2 EBI Track 200 track circuits comprises the following components:

a) EBI Track 200 Transmitter;
b) EBI Track 200 Receiver and relay;
c) Track tuning unit;
d) Impedance bond; and
e) End termination unit.

G 3.2.1.3.3 For train set compatibility, RIS-0725-CCS issue 1.1, part 3.3 for ac lines, gives guidance on the accepted limits for the susceptibility of EBI Track 200 track circuits to harmonics of the 50 Hz mains frequency, including how to assess train current against the susceptibility limits and track circuit centre frequencies.

G 3.2.1.3.4 If an exceedance of one of the two frequencies that EBI Track 200 track circuits operate on is emitted by a vehicle then the track circuit will most likely fail in a safe 'right-side' state. If a scenario where the two frequencies that a specific EBI Track 200 track circuit uses are emitted alternately by a vehicle, there is a risk that the track circuit will fail in an unsafe 'wrong-side' state. Such scenarios can occur as a result of frequency modulation characteristics of traction converters. RT/E/C/50008, part 6.2, gives more information on how rolling stock may interfere with EBI Track 200 track circuits.

G3.2.2 Track circuits found on dc railways

G3.2.2.1 50 Hz ac single and double rail track circuits

Guidance

G 3.2.2.1.1 For both 50 Hz ac single and double track circuits, when no vehicle is present in the section, current flows from a power supply source through one running rail, through the operating coil of a track circuit relay with normally closed contacts and returns via the other running rail. As a train enters the track circuit boundary, the impedance of the section reduces and results in the supply track circuit relay operating coil de-energising, opening the contacts and showing the section as occupied.

G 3.2.2.1.2 For train set compatibility, RIS-0725-CCS issue 1.1, part 4.1, gives guidance on the accepted limits for the susceptibility of 50 Hz ac single and double rail track circuits.

G3.2.2.2 Double rail reed track circuits

Guidance

G 3.2.2.2.1 Double rail reed track circuits on the dc railway are single frequency track circuits with the centre frequencies; 363 Hz, 366 Hz, 369 Hz, 372 Hz, 375 Hz, 378 Hz, 381 Hz, 384 Hz, 408 Hz, 417 Hz and 423 Hz, typically referred to by channel numbers f211 to f221.

G 3.2.2.2.2 Double rail reed track circuits on the dc railway comprises the following components:

a) Track filter;
b) Power amplifier (comprising transmitter amplifier and filter); and
c) Power supply.

G 3.2.2.2.3 For train set compatibility, RIS-0725-CCS issue 1.1, part 4.2, gives guidance on the accepted limits for the susceptibility of double rail reed track circuits.

G3.2.2.3 EBI Track 200 (dc lines)

Guidance

G 3.2.2.3.1 For train set compatibility, RIS-0725-CCS issue 1.1, part 4.3 for dc lines, gives guidance on the accepted limits for the susceptibility of EBI Track 200 track circuits, historically referred to as TI-21 track circuits, including how to assess train current against the susceptibility limits.

G3.2.2.4 FS2600 track circuits

Guidance

G 3.2.2.4.1 FS2600 track circuits transmit a frequency shift keyed (FSK) signal through the running rails into an impedance bond that is connected to an auxiliary coil and capacitor which results in the circuit being tuned to the track circuit carrier frequency. A receiver is located at the other end of the section, where both ends of the section are isolated by IRJs, and consists of similar components. If the receiver determines that the signal sent by the transmitter is correct, the section is considered clear, but if the signal is not the correct FSK waveform or not above a determined signal threshold, the section is considered occupied.

G 3.2.2.4.2 For train set compatibility, RIS-0725-CCS issue 1.1, part 4.4, gives guidance on the accepted limits for the susceptibility of FS2600 track circuits.

G3.2.3 Track circuits found on both ac and dc railways

G3.2.3.1 EBI Track 400 track circuits

Guidance

G 3.2.3.1.1 EBI Track 400 track circuits are of a similar design to EBI Track 200 track circuits, and typically use the same infrastructure equipment, but have the addition of a multi-bit coded telegram on their carrier frequency to provide 'wrong-side' immunity from traction interference and 'false feed' hazards.

G 3.2.3.1.2 For train set compatibility, RIS-0725-CCS issue 1.1, part 5.1, gives guidance on the accepted limits for the susceptibility of EBI Track 400 track circuits, including how to assess train current against the susceptibility limits.

G 3.2.3.1.3 Failure of EBI Track 400 track circuits typically reduce network performance, not network safety, as due to the technology used in these types of track circuits there is no credible scenario where a wrong-side failure can occur as explained in the guidance given in RIS-0725-CCS issue 1.1, section 5.1.

G3.2.3.2 High voltage impulse (HVI) track circuits

Guidance

G 3.2.3.2.1 High voltage impulse (HVI) track circuits are jointed and can be used on ac, dc or non-electrified lines. They are useful where tuned zones for jointless track circuits cannot be accommodated and for points and crossings where plain line audio frequency track circuits cannot be used.

G 3.2.3.2.2 HVI track circuits comprises the following components:

a) Power supply;
b) Transmitter;
c) Receiver; and
d) Track relay.

G 3.2.3.2.3 Susceptibility criteria for compatibility with HVI track circuits cannot be expressed as a simple emission level at a particular frequency or range of frequencies due to the nature of the waveform that is used.

G 3.2.3.2.4 RIS-0725-CCS issue 1.1, part 5.2, gives guidance on HVI track circuits including which train emissions should be analysed to assess compatibility with them.

G3.2.4 Track circuits found on non-electrified lines

Guidance

G 3.2.4.1 Limits for rolling stock axle-to-axle voltages for compatibility with the track circuit types listed below are set out within RIS-0725-CCS:

a) dc (non-ac immune);
b) Aster;
c) Western region quick release;
d) Lucas;
e) Reed jointless;
f) Overlay track circuits;
g) Diode track circuits;
h) Coded track circuits; and
i) 50 Hz track circuits.

G 3.2.4.2 NR/L2/SIG/50010 provides additional information on establishing EMC with these types of track circuits.

G3.3 Level crossing predictors

Guidance

G 3.3.1 There are few level crossing predictors installed in GB and they are on non-electrified lines. The areas where level crossing predictors are currently installed are attached as Appendix *B*.

G 3.3.2 Level crossing predictors are used to automatically close level crossings by estimating the time of arrival of a vehicle. A diagram of a typical level crossing predictor is given in Figure 8.

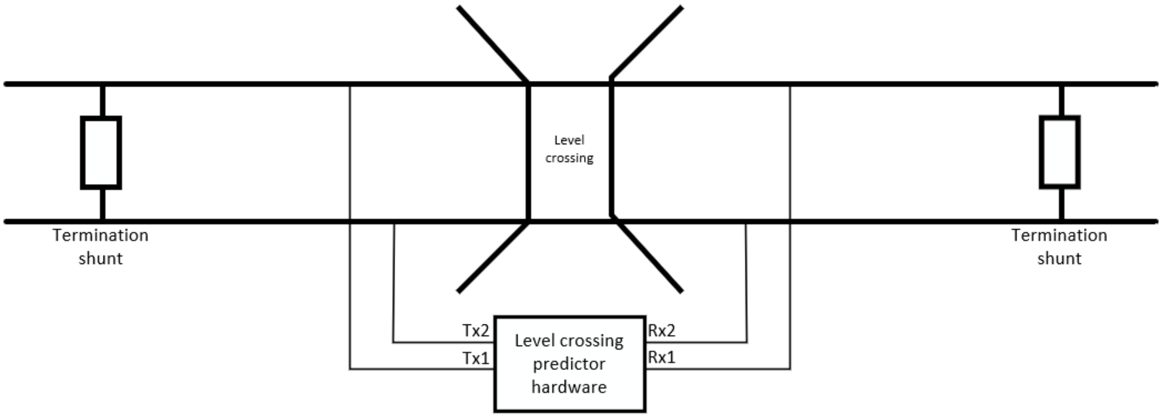

Figure 8: Level crossing predictor arrangement

G 3.3.3 When a vehicle passes over one of termination shunts as shown in Figure 8, the resulting amplitude and phase of a voltage that is generated due to a low audio frequency current injected into the running rails by a transmitter (Tx) and receiver (Rx) pair is received by the other Tx / Rx pair. This results in the equipment being able to calculate the impedance of the track section loop between the shunts. As the train moves towards the level crossing, the impedance of track section loop decreases towards zero, and then increases from zero until the train passes over the other termination shunt, at which point the level crossing is considered to be clear. The rate of change of impedance can be used to determine the speed of the train.

G 3.3.4 Two level crossing predictor types operating in the frequency range of 85 Hz - 1 kHz are known to be in operation in GB which are:

a) GETS Harmon HXP-3; and
b) WESTeX GCP 3000.

G 3.3.5 The GETS Harmon HXP-3 level crossing predictor injects frequencies into the running rails in the range 100 - 250 Hz.

G 3.3.6 When a train is traversing the level crossing, the Rx voltage remains at zero and the level crossing predictors cannot detect motion by measuring the impedance. To overcome the problem identified, the HXP-3 transmits randomly coded short bursts of a 8.3 kHz signal between Tx1 / Tx2 and Rx1 / Rx2, as shown in Figure 8, to accurately determine whether there is a train in the level crossing and when the last axle has cleared the level crossing before allowing the crossing to clear.

G 3.3.7 The susceptibility limits for both level crossing predictor types in operation in GB are unknown and therefore comprehensive type testing is typically performed to understand compatibility between rolling stock and level crossing predictors.

G3.4 Automatic Warning System (AWS)

Guidance

G 3.4.1 Rolling stock that produces a static, such as dc, magnetic flux density between the running rails at running rail level of more than 24×10^{-3} Tesla for a time greater than 0.01 seconds, or greater than $24 \times 10^{-6}/t^2$ Tesla , where t is seconds for times shorter than 0.01 seconds, can result in incompatibility with AWS equipment.

G 3.4.2 RIS-0775-CCS gives guidance on AWS EMC which includes the effect dc cross-track feeder cables can have on onboard receivers and general guidance on external sources of EMI into the AWS subsystem.

G3.5 Train Protection and Warning System (TPWS)

Guidance

G 3.5.1 TPWS provides the functions of a Train Stop System (TSS) and an Overspeed Sensor System (OSS). An emergency brake application will occur on a train fitted with TPWS equipment if an active TSS is passed or an OSS is passed over at excessive speed and detects the relevant arming loop first.

G 3.5.2 The TPWS trackside system comprises of the following components:

a) Transmitter driver modules;
b) Trigger and arming transmitter loops; and
c) Power supply and signaling interface unit.

G 3.5.3 TPWS transmits un-modulated tones from transmitter loops located in the track which are received by an antenna on the train.

G 3.5.4 There are two types of transmitter loops installed on the GB network; standard and mini. Mini loops are typically installed on the approach to buffer stops at terminus platforms.

G 3.5.5 The frequency range over which TPWS operates is 62.25 - 66.75 kHz. The TPWS system is susceptible to magnetic fields at the train receiver in this frequency band and GERT8075 sets out the susceptibility limits.

G 3.5.6 The standard loop system is immune to interference above 700 Hz and the mini loop is immune to interference above 1 kHz. Susceptibility limits for frequencies up to these values are given in NR/SP/SIG/50012, Figure 4.

G 3.5.7 The cable between a transmitter driver module and both types of transmitter loops can be particularly susceptible to induced voltages; however, the cables are typically screened twisted pair type with short exposed lengths, which mitigates interference.

G 3.5.8 RIS-0775-CCS sets out requirements and guidance for TPWS onboard subsystem receiver aerial positioning that mitigates EMI that can be caused by audio frequency track circuit systems.

G3.6 Axle counters

Guidance

G 3.6.1 Axle counting sensors are mounted to the running rails at the ends of a section of track and can determine train direction and speed.

G 3.6.2 Axle counter trackside equipment typically comprises of the following components:

a) Evaluator unit;
b) Electronic junction box; and
c) Rail contacts.

G 3.6.3 Limits for magnetic fields and the equivalent harmonic content of running rail current applicable to compatibility between rolling stock and axle counters of types; AzL70, AzL70-30, AzLM, AzSME and ACS2000 are defined in NR/SP/SIG/50011. This includes consideration of communication between the axle counter head and the evaluator.

G 3.6.4 Interference limits and evaluation criteria for electromagnetic compatibility between rolling stock and axle counter detectors compliant with BS EN 50617-2:2015 are defined within PD CLC/TS 50238-3:2022, which is used in conjunction with BS EN 50238-1:2019. An example of an axle counter type compliant with BS EN 50617-2:2015 is the Frauscher Advanced Counter (FAdC).

G 3.6.5 Presumption of conformity to requirement ERA ERTMS 033281 v5.0, clause 3.2.1.4, is assumed if a system is assessed against BS EN 50592:2016. If the limits of ERA ERTMS 033281 v5.0, clause 3.2.1.4, are not met then individual assessment of EMC with each axle counter type on a route is performed.

G3.7 Lineside equipment

Guidance

G 3.7.1 The ERTMS Eurobalise operates at:

a) 27 MHz between the train and transponder; and
b) 4.5 MHz from the transponder to the train.

G 3.7.2 CCS NTSN Subset-036, the form fit function interface specification for Eurobalise, requires Eurobalises to comply with Tables 1 and 2 of EN 50121-4. The susceptibility of the system at its operating frequencies is not defined.

G3.8 Route relay and solid state interlocking

Guidance

G 3.8.1 Route relay interlocking (RRI) is the setting and releasing of routes and the safe control of signals, points and other items of trackside equipment by using dc relay technology. The system consists of discrete relays , such as free-wired interlocking, or ready-made standard units with additional discrete relays, such as geographical interlocking. The relays are miniature dc active armature types.

G 3.8.2 Solid state interlocking (SSI) is based on the use of programmable solid-state electronics, for example microprocessors, to carry out the setting and releasing of routes and the safe control of signals, points and other items of trackside equipment. Redundancy techniques are used to enable safe operation and the interlocking is controlled by software which interprets geographic data specific to a particular installation. Both software and data are subject to a rigorous validation process to control the risk of systematic errors.

G 3.8.3 Voltage spikes can occur between the running rails and earth on the GB 25 kV ac mainline railway when a spark occurs between the pantograph and OCL. The magnitude and duration of a spike both increase with increasing pantograph to body capacitance and with increasing rail-earth impedance.

G 3.8.4 The voltage spikes appearing on the rails are transferred directly to SSI equipment via track circuit tail cables. These voltage spikes have very steep leading edges and can be transferred into trackside functional modules (TFMs) directly through electrical breakdown within the relays, or indirectly via parasitic capacitance or earth connections.

G 3.8.5 A reference system approach where a pantograph to body capacitance that is no greater than that on existing traction units can be used to demonstrate compatibility with interlocking systems.

G 3.8.6 Frequencies greater than 10 kHz at 20 V peak-to-peak measured longitudinally on a cable can result in telegram reception problems at both interlocking and trackside and can also cause over-transmissions where data link module (DLM) repeaters are involved.

G 3.8.7 NR/GN/SIG/50013 gives more information on electromagnetic compatibility with RRI and SSI.

Appendices

Appendix A Psophometric weighting curve

A.1 General

Guidance

G A.1.1 Psophometric weighting is used in measuring noise on telecoms circuits and is the application of a type of frequency selective filter that has high gain in the mid-range frequencies and low gain in the low and high range frequencies, resulting in the amplification of potentially problematic voltages which may otherwise not be heard. International telecommunications union (ITU) specification ITU-T O.41 contains further information on the application of psophometric weighting to telecoms circuits in general.

G A.1.2 The values given in Table *7* and Figure *9* were established based on those set out in ITU specification ITU-T O.41 but converted to have a unitless weighting factor, where the ITU specification sets out the relative weight at each frequency in decibels and includes a tolerance for each.

Frequency (Hz)	Weighting factor (unitless)
50	0.00071
100	0.00891
200	0.08910
300	0.29499
400	0.48399
500	0.66100
550	0.72748
600	0.79398
700	0.89843
800	1.00000
900	1.06265
1000	1.12199
1200	1.00000
1400	0.90178
1600	0.82399
1800	0.76056
2000	0.70801
2500	0.61699
3000	0.52498
3500	0.37599
4000	0.17799
4500	0.04974
5000	0.01590
5500	0.01590
6000	0.01590

Table 7: Psophometric weighting curve values

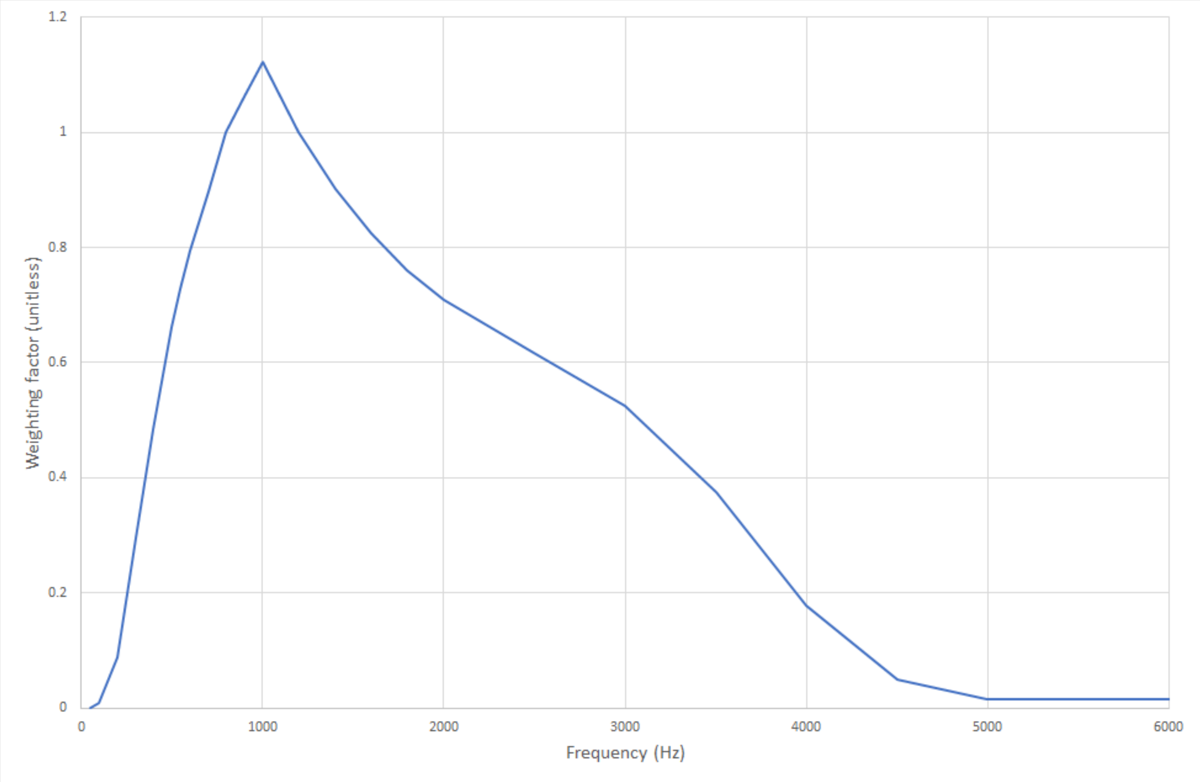

Figure 9: Graphical representation of the psophometric weighting curve

Appendix B Level crossing predictor locations

B.1 General

Guidance

G B.1.1 The following location information is based on known Network Rail data on the installations of WESTeX GCP 3000 and GETS Harmon HXP-3 level crossing predictors as referred to in Network Rail document reference number EMC-SC-TA-NR_GCP3000_HXP3 _01_2023-01-06 (not an exclusive list and there may be installation elsewhere on the network):

a) WESTeX GCP 3000 level crossing predictors:
- Several in the Lincoln delivery unit area
- Several in the Drax area, Yorkshire
- Kirby Muxloe (East Midlands Route)

b) GETS Harmon HXP-3 level crossing predictors:
- Bedford - Bletchley (Marston Vale Line)
- Whitlingham Junction - Cromer - Sheringham (Cromer Line)
- Thorpe Road Level Crossing (Line of Route LN888, Engineers Line Reference CJS0)

Definitions

affected system	The system which is affected by electromagnetic interference
analogue (signal)	Signal in which characteristic quantity representing information can at any instant assume any value within a continuous interval. Source: *IEV 702-04-02*
cable	An insulated current carrying conductor or conductors.
capacitive coupling	Coupling between electric circuit elements, by which a voltage between the terminals of one of them gives rise to an electric charge in another element. Source: *IEV 131-12-31*
conductive coupling	Phenomenon whereby a part of the current of a power system returns to the system earth via the conductors of another system. Source: *IEV 614-04-02*
conductor rail	Rigid metallic conductor mounted on insulators intended to interface with a vehicle mounted current collector. Source: *BS EN 50122-1:2022*
digital (signal)	A discretely timed signal in which information is represented by a finite number of well defined discrete values that one of its characteristic quantities may take in time. Source: *IEV 702-04-05*
electric traction supply system	Railway electric distribution network used to provide energy for rolling stock. Source: *BS EN 50388-1:2022*
electromagnetic compatibility (EMC)	The ability of equipment or a system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.
electromagnetic interference (EMI)	Degradation in the performance of equipment or transmission channel or a system caused by an electromagnetic disturbance. Source: *IEV 161-01-06*
electromagnetic susceptibility	The inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance. Source: *IEV 161-01-21*
extended return circuit	Part of the electric traction power supply system which is not live, which leads the current back from loads such as vehicles or other equipment to the source. Source: *BS EN 50122-1:2022*
finite element method magnetics (femm)	An open-source software that can simulate electromagnetic and electrostatic problems
frequency selective system	A system that is sensitive, and responds, to different frequencies [in contrast to one which functions over a broad frequency range such as for voice communication]
frequency shift keying	Angle modulation in which each significant condition of a modulating discretely timed signal is represented by one of a specified set of discrete values of the frequency of the modulated signal. Source: *IEV 702-06-47*

harmonic frequency	Frequency which is an integer multiple greater than one of the fundamental frequency or of the reference fundamental frequency. Source: *IEV 551-20-05*
induced coupling	Coupling between electric circuit elements, by which an electric current in one of them gives rise to a total flux ψ_{AB} between the terminals of another element. Source: *IEV 131-12-33*
infrastructure manager (IM)	Has the meaning given to it in the Railways and Other Guided Transport Systems (Safety) Regulations 2006 (as amended), but is limited to those infrastructure managers who hold a safety authorisation issued in respect of the mainline railway. Source: *ROGS*
interference current	Current caused on the affected system by electromagnetic coupling with a nearby source system between a given point and the earth or across an insulating joint
interference source	Equivalent to traction unit which is fed from its own power supply interface point (pantograph or shoe gear) . Source: *PD CLC/TS 50238-2:2020*
interference voltage	Voltage caused on the affected system by electromagnetic coupling with the nearby source system between a given point and the earth or across an insulating joint
line current	The current drawn by a train from the traction supply and returned from the train into the rails. Where current is returned to the rails at more than one point, this is the vector sum of current from all return points within the train.
magnetic flux	Scalar quantity equal to the flux of the magnetic flux density **B** through a given directed surface
management voltage	General name encompassing all the induced voltages to be used to evaluate if an interference situation is acceptable, such as the limit values related to danger to people working on the telecommunication plant; the limit value related to noise; the minimum resistibility voltage level of the equipment connected to the telecommunication plant; the minimum insulation withstand voltage level of the telecommunication plant; the minimum immunity voltage level of the equipment connected to the telecommunication plant. Source: *ITU-T K.68*
neighbouring railway	A railway network operating adjacent to the GB mainline, for example, London Underground
overhead contact line (OCL)	Contact line placed above (or beside) the upper limit of the rail vehicle gauge and supplying vehicles with electric energy through roof-mounted current collection equipment. Sources: *IEV 811-33-02, ENE NTSN*

Note: Where this includes, in addition to all current-collecting conductors, the following elements:

reinforcing feeders; cross-track feeders; disconnectors; section insulators; overvoltage protection devices; supports that are not insulated from the conductors; insulators connected to live parts; along-track feeders; conductors connected permanently to the contact line for supply of other electrical equipment; earth wires and return conductors.

psophometric noise	Electronic circuit noise relating to analogue telecommunications equipment where its presence in the output of power supplies can significantly impair audio transmission quality.
psophometric weighting	A noise weighting established by the International Consultative Committee for Telephony (CCIF, which became CCITT and, more recently, ITU-T), designated as CCIF-1951 weighting, for use in a noise measuring set or psophometer. Source: *Telecommunications Industry Association Glossary of Telecommunications Terms*
radiated disturbance	Electromagnetic disturbance for which the energy is transferred through space in the form of electromagnetic waves. Source: *IEV 161-03-21*
return circuit	All conductors which form the intended path for the traction return current. **Note:** Therefore, so far as this aspect is concerned, the return circuit is part of the energy subsystem and has an interface with the infrastructure subsystem. Source: *ENE NTSN*
return conductor rail	Conductor rail used instead of the running rails for the traction return currents. Source: *BS EN 50122-1:2022*
rolling stock	All vehicles with or without motors. Source: *BS EN 50388-1:2022*
sources	Any interference source which can generate harmonics independently. Source: *PD CLC/TS 50238-2:2020*
telegram	A series of positive and negative voltages with varying peaks and troughs which look like a square shaped waveform on an oscilloscope. A telegram is a binary transmission of an analogous output from a system and is typically used in conjunction with coding techniques, such as Manchester Coding, a type of Binary Phase Shift Keying (BPSK). This results in a signal either being a '0' or '1' value with no exception as a result of tolerances applies to the analogous signal, for example a '1' value being attributed to any signal over a given threshold.
track circuit (TC)	A type of train detection system that detects the presence or absence of a rail vehicle within a defined section of track, by means of the electrical circuit created between the running rails by one or more wheelsets.

track return system	System in which the running rails of the track form a part of the return circuit for the traction current. Source: *BS EN 50122-1:2022*
traction power supply system	Part of the overall electricity energy supply system, not extending beyond the dedicated feeder stations on the rail network. Source: *BS EN 50238-1:2019*
traction power unit	The unit on the train housing the converter/inverter equipment and its associated control to drive the propulsion system. It is also known as the motor car. Source: *PD CLC/TS 50238-2:2020*
traction stock	Electric and diesel locomotive, high speed trainset, elementary fixed combination of traction stock and hauled stock, electric and diesel multiple unit (no locomotive, distributed traction equipment), Light Railway Vehicle (LRV) such as tram, trolley bus or any other electrical vehicle for urban mass transit, underground trainset Source: *BS EN 50121-3-1:2017+A1:2019*
traction subsystem	Any subset of the Traction Unit which produces traction force or electric brake force. Source: *PD CLC/TS 50238-2:2020*
traction unit	Locomotive, motor coach or train-unit. Source: *BS EN 50388-1:2022*
train detection system	Equipment and systems forming part of, or providing input to, the signalling systems to detect, either: • The presence or absence of vehicles within the limits of a track section • That a train has reached, is passing, or has passed a specific position.
train set	Combination of vehicles coupled together, including banking locomotives. Source: *BS EN 50388-1:2022*
train under test	The influencing unit used for the test measurements. Source: *PD CLC/TS 50238-2:2020*
transfer function	Ratio of the complex quantity representing a time-varying quantity in terms of complex frequency at the output of a linear time-invariant two-port, to the complex quantity representing the corresponding input quantity, the two complex quantities being defined in the same manner **Note:** The complex quantities are generally the Laplace transforms of the time-varying quantities. In this case, the transfer function is the Laplace transform of the impulse response, and the term "fonction de transfert isomorphe" is used in French. Source: *IEV 131-15-20*
transient	Pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval short compared with the time-scale of interest. Source: *IEV 702-07-78*

transverse voltage	The difference in voltage magnitude and phase across two adjacent cables at the terminus connection point
vehicle	An individual vehicle or car of any train formation.
wire	Flexible cylindrical conductor, with or without an insulating covering, the length of which is large with respect to its cross-sectional dimensions. Source: *IEV 151-12-28*

References

The Standards catalogue gives the current issue number and status of documents published by RSSB: http://www.rssb.co.uk/standards-catalogue.

RGSC 01	Railway Group Standards Code
RGSC 02	Standards Manual

Documents referenced in the text

RSSB documents

GLRT1212	DC Conductor Rail Energy Subsystem and Interfaces to Rolling Stock Subsystem
GLRT1210	AC Energy Subsystem and Interfaces to Rolling Stock Subsystem
RIS-0725-CCS	Electromagnetic Compatibility of Train Detection Infrastructure with Rail Vehicles

Other references

BS EN 50121-3-1:2017 +A1:2019	Railway applications. Electromagnetic compatibility - Rolling stock. Train and complete vehicle
BS EN 50238-1:2019	Railway applications. Compatibility between rolling stock and train detection systems - General
BS EN 50592:2016	Railway applications. Testing of rolling stock for electromagnetic compatibility with axle counters
BS EN 50617-2:2015	Railway Applications. Technical parameters of train detection systems for the interoperability of the trans-European railway system - Axle counters
Command Control and Signalling National Technical Specification Notice (CCS NTSN)	Command Control and Signalling National Technical Specification Notice (CCS NTSN). Published by the Secretary of State on 1 January 2021 pursuant to regulation 3B of the Railways (Interoperability) Regulations 2011. This Notice replaces and substantially reproduces the provisions of Commission Regulation (EU) 2016/919 of 27 May 2016 (the CCS TSI) and includes relevant amendments made by Commission Implementing Regulation (EU) 2019/776 which came into force in June 2019.
EMC SG Presentation 10/04/2019	Calculation of Transverse Voltage across the telecomms pair using FEMM software: Part 2: Validation of FEMM calculated transfer function β with practical measurements and conversion to weighting curve for train current emissions
EMC SG Presentation 11/07/2019	Calculation of Transverse Voltage across the telecomms pair using FEMM software: Part 3: Variation of FEMM calculated transfer function β for different configurations and comparison with practical measurements

EMC SG Presentation 15/10/2020	Calculation of Transverse Voltage across the telecomms pair using FEMM software: Part 5: Comparison of FEMM calculated transfer function β with practical test measurements
EMC SG Presentation 24/01/2018	Calculation of Transverse Voltage across the telecomms pair using FEMM software
EN 50121-4	Railway applications. Electromagnetic compatibility - Emission and immunity of the signalling and telecommunications apparatus
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ITU-T K.68	Operator responsibilities in the management of electromagnetic interference by power systems on telecommunication systems.
ITU-T O.41	Specifications for measuring equipment. Equipment for the measurement of analogue parameters. Psophometer for use on telephone-type circuits.
NR/GN/SIG/50008	Methodology for the Demonstration of Compatibility with TI 21 Track Circuits
NR/GN/SIG/50013	Methodology for the demonstration of compatibility with route relay and solid state interlockings
NR/GN/SIG/50015	Methodology for the demonstration of electrical compatibility with reed FDM systems on the AC and DC railways
NR/L2/SIG/50004	Methodology for the Demonstration of Electrical Compatibility with DC (AC Immune) Track Circuits
NR/L2/SIG/50010	Methodology for the Demonstration of Electrical Compatibility with Train Detection Systems in Use on Non-electrified Lines
NR/SP/SIG/50011	Methodology for the demonstration of compatibility with axle counters
NR/SP/SIG/50012	Methodology for the Demonstration of Compatibility with TPWS Track Sub-system
NR/SP/TEL/50016	Methodology for the Demonstration of Compatibility with Telecommunications Systems
PD CLC/TS 50238-2:2022	Railway applications. Compatibility between rolling stock and train detection systems - Compatibility with track circuits

RT/E/C/50008	Methodology for the demonstration of compatibility with TI 21 track circuits

Other relevant documents

EMC-SC-TA-NR_GCP3000_HXP3_01_2023-01-06	Summary Notes - Installations of GCP 3000 and HXP3 Level Crossing Predictors
IEC 60050-131:2004/AMD4:2021	Amendment 4 - International Electrotechnical Vocabulary (IEV) - Part 131: Circuit theory
IEC 60050-151:2001/AMD5:2021	Amendment 5 - International Electrotechnical Vocabulary (IEV) - Part 151: Electrical and magnetic devices
IEC 60050-161:1990/AMD10:2021	Amendment 10 - International Electrotechnical Vocabulary (IEV) - Part 161: Electromagnetic compatibility
IEC 60050-551-20:2001/AMD1:2017	Amendment 1 - International Electrotechnical Vocabulary (IEV) - Part 551-20: Power electronics - Harmonic analysis
IEC 60050-614:2016	International Electrotechnical Vocabulary (IEV) - Part 614: Generation, transmission and distribution of electricity - Operation
IEC 60050-702:1992/AMD6:2021	Amendment 6 - International Electrotechnical Vocabulary (IEV) - Part 702: Oscillations, signals and related devices
ITU-T K.10	Low frequency interference due to unbalance about earth of telecommunication equipment
ITU-T K.26	Protection of telecommunication lines against harmful effects from electric power and electrified railway lines
ITU-T K.34	Classification of electromagnetic environmental conditions for telecommunication equipment - Basic EMC Recommendation
ITU-T K.42	Preparation of emission and immunity requirements for telecommunication equipment - General principles