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Electromagnetic Compatibility of Train Detection Infrastructure with Rail Vehicles

Synopsis

This document is a standard on immunity levels of infrastructure-based train detection systems, to provide electromagnetic compatibility (EMC) with emissions from trains.

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One	02/12/2017	This document sets out values for EMC parameters for CCS infrastructure subsystems.

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Supply

The authoritative version of this document is available at www.rssb.co.uk/railway-group-standards. Enquiries on this document can be forwarded to enquirydesk@rssb.co.uk.

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Part 1 Purpose and Introduction

1.1 Purpose

1.1.1 This document is a standard on immunity levels of infrastructure-based train detection systems, to provide a generally acceptable level of electromagnetic compatibility (EMC) with emissions from trains. Compliance of Control Command and Signalling Trackside (CCT) subsystems with these immunity levels will assist designers and operators of trains in the demonstration of technical compatibility.

1.2 Background

1.2.1 Electromagnetic interference (EMI) can adversely affect technical compatibility of train detection infrastructure with rail vehicles. This standard sets out limits for parameters which provide a target for immunity levels, which will assist in the achievement and demonstration of EMC between train detection systems and rail vehicles.

1.2.2 Conformity to these limits helps to control the susceptibility of CCT infrastructure to EMI to maintain agreed levels of immunity and support assessment of compatibility. This will provide efficiencies in the process of obtaining authorisation to place into service for new rail vehicles and infrastructure where generic train detection infrastructure complies with current standards, and may reduce the need for additional EMC assessment as part of the safe integration process before changes are put into use.

1.2.3 The infrastructure susceptibility limits specified in this standard have been derived from values which have previously been used as a basis for EMC assessment. These include values published in the ‘50000’ series of Network Rail standards, and other documentation provided by equipment manufacturers.

1.2.4 This document does not specify susceptibility levels for legacy axle counters; the majority of existing axle counters currently on the Great Britain (GB) mainline railway are covered by the requirements of European Rail Agency (ERA) document ERA/ERTMS/033281 (referenced in TSI CCS as ‘Index 77’). Information on the susceptibility of older types of axle counters which might not be compliant with ERA/ERTMS/033281 is given in Network Rail document NR/SP/SIG/50011.

1.2.5 Requirements on the management of EMC between railway infrastructure and rail vehicles other than that between CCT train detection equipment and rail vehicles are not covered in this standard. RIS-8270-CCS sets out requirements and responsibilities for the assessment of route compatibility of vehicles and infrastructure.

1.3 Intended use of this document

1.3.1 EMI is one of the potential hazards that is managed to achieve safe integration of changes to the railway. Before a change to the infrastructure or rail vehicles is put into use, the proposer identifies whether the hazard of EMI is present and, if it is, undertakes an EMC assessment as part of the route compatibility assessment.

1.3.2 The EMC part of route compatibility assessment takes account of normal and degraded modes of operation, including assessment of the effects of transients on the operation of CCT subsystem equipment. Available information on susceptibility of degraded infrastructure is included in this document as guidance.

1.3.3 While this document specifies immunity limits to be achieved by infrastructure, these limits can be used to inform the design and EMC assessment of rail vehicles. Conformance with these limits will facilitate effective demonstration of compatibility. Information is also included on historical limits for types of track circuit which are no longer used for new installation but are still present on the GB mainline railway network.

1.3.4 This document is available as a code of practice that can be used by a Proposer when applying the Common Safety Method on Risk Evaluation and Assessment (CSM RA) risk acceptance principles to a planned change before it is put into use. The Proposer can be an infrastructure manager or a railway undertaking.

1.3.5 The data in this document can be used in combination with an EMC assessment to identify the safety requirements needed to control the hazard of a train detection system failure caused by conducted electromagnetic interference from trains.

1.3.6 An Applicant seeking an 'Authorisation for Placing into Service' of a rail vehicle or train detection infrastructure in accordance with the Railways (Interoperability) Regulations 2011 can use the information in this document in support of an argument to close the EMC open points on conducted interference in the CCS TSI (reference ERA/ERTMS/033281 Interfaces between Control-Command and Signalling Trackside and Other Subsystems; section 3.2.2 Conducted interference).

1.4 Application of this document

1.4.1 Compliance requirements and dates have not been specified since these will be the subject of internal procedures or contract conditions.

1.4.2 The Standards Manual and the Railway Group Standards (RGS) Code do not currently provide a formal process for deviating from a Rail Industry Standard (RIS). However, a member of RSSB, having adopted a RIS and wishing to deviate from its requirements, may request a Standards Committee to provide opinions and comments on their proposed alternative to the requirement in the RIS. Requests for opinions and comments should be submitted to RSSB by e-mail to proposals.deviation@rssb.co.uk. When formulating a request, consideration should be given to the advice set out in the 'Guidance to applicants and members of Standards Committee on deviation applications', available from RSSB's website.

1.5 Health and safety responsibilities

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1.6 Structure of this document

1.6.1 This document sets out a series of requirements that are sequentially numbered.

1.6.2 This document also sets out the rationale for the requirement. The rationale explains why the requirement is needed and its purpose. Rationale clauses are prefixed by the letter 'G'.

1.6.3 Where relevant, guidance supporting the requirement is also set out in this document by a series of sequentially numbered clauses and is identified by the letter 'G'.

1.7 Approval and Authorisation

1.7.1 The content of this document was approved by Control Command and Signalling (CCS) Standards Committee on 31 August 2017.

1.7.2 This document was authorised by RSSB on 20 October 2017.

Part 2 Requirements for EMC Interface Parameters for Train Detection Systems

2.1 New types of infrastructure-based train detection system

2.1.1 New track circuit products shall conform to BS EN 50617-1:2015.

2.1.2 New axle counter system products shall conform to BS EN 50617-2:2015.

Rationale

G 2.1.3 EMC of new types of infrastructure-based train detection systems with rail vehicles.

Guidance

G 2.1.4 BS EN 50617-1:2015 and BS EN 50617-2:2015 set out the EMC requirements for interoperable train detection systems, and define frequency management criteria which can be used to address the EMC open point in the 'Index 77' specification referenced by the CCS TSI.

G 2.1.5 BS EN 50617-1 specifies the requirements for design of new track circuit systems.

G 2.1.6 BS EN 50617-2 specifies the requirements for design of new axle counter systems.

2.2 New and modified track circuit equipment of legacy design types

2.2.1 New and modified track circuits of legacy types shall be configured:

a) Using only the track circuit types set out in Parts 3, 4 and 5.
b) So that the track circuits are capable of maintaining the design operating state and expected level of performance in the presence of the maximum train emission levels set out in Parts 3, 4 and 5.

Rationale

G 2.2.2 Technical compatibility of legacy types of track circuit with rail vehicles.

G 2.2.3 EMI can adversely affect the correct and reliable operation of track circuits. This includes traction return currents conducted into the rails and axle-to-axle voltages (a potential difference between the wheelsets of a train).

G 2.2.4 The types of track circuit set out in this document represent a significant proportion of the CCT infrastructure on the GB mainline railway. The target EMC immunity levels for these legacy types of track circuit, which are set out in Parts 3 to 5 of this document, are accepted standards of immunity of track circuits to EMI from trains.

G 2.2.5 Limiting new applications of track circuits to these types is consistent with migrating to a defined EMC infrastructure immunity target.

Guidance

G 2.2.6 Excessive EMI can be a cause of the following track circuit failure modes:

a) False energisation of a track circuit receiver when the track section is occupied by a rail vehicle, resulting in loss of detection (track section showing clear when occupied).
b) De-energisation of a track circuit receiver when the section is not occupied by a rail vehicle (track section showing occupied when clear), due to EMI entering the track section from a train on another track section.

G 2.2.7 Configuration of track circuits includes the technical design and physical parameters of the train detection infrastructure necessary to achieve the target level of immunity to EMI.

G 2.2.8 The specified immunity limits are based on analysis of existing track circuit systems to identify the levels of current and axle-to-axle voltage per train to which track circuits that are designed and installed to appropriate standards are immune.

G 2.2.9 The maximum rail current values are specified as maximum line current 'per train'. This is the total current in the specified frequency range introduced by a train into the running rails; this current might be divided equally between the two rails or might flow wholly or predominantly in one rail. This provides a target limit for emissions from a train that can be used by rail vehicle suppliers to inform the design of the train.

G 2.2.10 In order to identify the maximum level of current from all trains to which an individual element of the train detection system may be exposed, the configuration and maintenance of track circuits take into account:

a) The number of trains that could simultaneously introduce current into a track section.
b) The design and configuration of the energy (electric traction supply) subsystem, particularly in regard to the distribution of current between alternative paths.

Part 3 Track Circuits on AC Electrified Lines

3.1 DC (AC immune) track circuits

3.1.1 DC (AC immune) track circuits shall be capable of detecting rail vehicles in the presence of the EMI levels set out in Table 1.

Maximum DC rail current (steady state) (per train)	Maximum DC axle-to-axle voltage (steady state)
3.81 A	832 mV

Table 1: Compatibility limits for DC track circuits on AC electrified lines

Rationale

G 3.1.2 EMC of DC (AC immune) track circuits with rail vehicles.

G 3.1.3 Excessive rail current or DC axle-to axle-voltage can result in false operation of a DC (AC immune) track circuit.

Guidance

G 3.1.4 Reliable operation of DC track circuits can be affected by EMI from trains, which conduct traction return currents into the rails and produce axle-to-axle voltages between the wheelsets.

G 3.1.5 For the purpose of specifying compatibility limits, DC (AC immune) track circuits are divided into two categories:

a) Medium voltage track circuits fitted with DC track relays of the following types:
   i) BR939A.
   ii) BR966 F2.
   iii) BR966 F9.
b) Low voltage track circuits fitted with track relays of other types.

G 3.1.6 The limits set out in Table 1 can be achieved using medium voltage track circuits installed in conformity with standard installation parameters.

G 3.1.7 The 3.81 A limit is based on historical modelling of DC track circuits using medium voltage relays described in Network Rail document NR/SP/SIG/50004, assuming the following infrastructure configuration, which was assessed to represent the most susceptible conditions for DC interference:

a) Double track layout.
b) Jointed track.
c) 25 kV 50 Hz electrification.
d) Traction return via the running rails.
e) Type BR939A relay.
f) Track circuit of maximum length permitted by installation standards.

G 3.1.8 The 832 mV limit is derived from the historical modelling in NR/SP/SIG/50004 based on a track circuit fitted with a BR966 F2 relay, which was shown to be the most susceptible type of medium voltage DC track relay to axle-to-axle voltage with intact infrastructure.

G 3.1.9 Both limits take into account transmitter breakthrough and an allowance for the presence of other trains, and incorporate a 20 % safety margin.

G 3.1.10 For the purpose of determining susceptibility to low frequency interference, the response of a DC track relay is considered to be represented by a composite frequency response curve which can be modelled as a cascade of two single pole Butterworth low pass filters with –3 dB points at 0.5 Hz and 4.14 Hz.

G 3.1.11 Further detail of the historical modelling is set out in NR/SP/SIG/50004. This modelling covers DC track circuits using both medium voltage and low voltage track relays. The infrastructure target for EMC susceptibility is based on the provision of medium voltage track circuits. Existing low voltage DC track circuits might not meet these limits; if low voltage track circuits are modified, they would be limited to a restricted range of installation parameters in order to comply with these limits. The information on low voltage DC track circuits in NR/SP/SIG/50004 may still be applicable to assessing compatibility with existing track circuits of this type.

G 3.1.12 NR/SP/SIG/50004 identifies a lower maximum rail current limit of 1.18 A for DC (AC immune) track circuits on a double track line, or 0.62 A on a single track line, allowing for degraded infrastructure conditions, for example a break in a section of the traction return circuit. Consideration of the impact of infrastructure failures on EMC is part of the route compatibility assessment.

G 3.1.13 Under certain failure conditions, and in some atmospheric conditions such as those leading to a build-up of ice on the overhead line, there is a possibility that trains might exceed the maximum current limit, and the risk from false energisation of track circuits will need to be considered as part of the route compatibility assessment.

G 3.1.14 To assess the effect of DC transients produced by rolling stock, one approach is to undertake a comparative assessment with existing rolling stock operating on the route.

G 3.1.15 NR/SP/SIG/50004 gives values for transformer inrush for trains operating over infrastructure fitted with DC (AC immune) track circuits. This includes different permissible values for locomotives and EMUs, representing levels of transformer inrush based on a range of types of rolling stock then in service. The values in Table 2 below are based on the higher of the limits shown in NR/SP/SIG/50004, which were for locomotives.

Parameter	Value
First peak of current	< 400 A
DC current 1 s after first peak	< 20 A

Parameter	Value
Interval between successive inrush transients	> 5 s

Table 2: Transient current limits for DC track circuits

G 3.1.16 Where these values cannot be achieved, NR/SP/SIG/50004 provides guidance on using a risk-based comparison against existing rolling stock that operates on the route without showing evidence of transient interference to DC track circuits.

3.2 Reed track circuits (AC lines)

3.2.1 Reed track circuits on AC electrified lines shall be capable of detecting rail vehicles in the presence of the EMI levels set out in Table *3*.

Frequency		Maximum steady state rail current (per train)	Maximum steady state axle-to-axle voltage
Designation	Hz		
f211	363	90.2 mA	99 mV
f212	366		
f213	369		
f214	372		
f215	375		
f216	378		
f217	381		
f218	384		
f219	408		
f220	417		
f221	423		

Table 3: Compatibility limits for reed track circuits on AC electrified lines

3.2.2 Reed track circuits on AC electrified lines shall meet the values set out in Table *3* for a half-power (-3 dB) bandwidth of 0.5 Hz.

Rationale

G 3.2.3 EMC of reed track circuits with rail vehicles.

G 3.2.4 Excessive rail current or axle-to-axle voltage at reed frequencies can result in false operation of a reed track circuit.

G 3.2.5 Reed track circuits are susceptible to interference at their operating frequency, which is a single unmodulated frequency determined by a narrow bandwidth mechanical reed filter. The specified bandwidth criteria represent the frequency response of the reed track circuit receiver.

Guidance

G 3.2.6 Reliable operation of reed track circuits can be affected by EMI from trains, which conduct traction return currents into the rails and produce axle-to-axle voltages between the wheelsets.

G 3.2.7 The limits set out in Table *3* are based on historical modelling of a single rail reed track circuit in Network Rail document NR/SP/SIG/50002, which assumed the following infrastructure configuration, assessed to represent the most susceptible conditions to EMI for intact infrastructure:

a) Single track line.
b) Reed track circuit in single rail mode.
c) Most sensitive receiver setting.
d) Maximum track circuit length 1200 m.

G 3.2.8 Further detail of the modelling of a single rail reed track circuit is set out in NR/SP/SIG/50002.

G 3.2.9 NR/SP/SIG/50002 identifies a lower maximum rail current limit of 82.5 mA for degraded infrastructure conditions, for example a break in a section of the traction return circuit. Consideration of the impact of infrastructure failures on EMC is part of the route compatibility assessment.

G 3.2.10 Further details of the frequency response of the reed track circuit receiver are set out in NR/SP/SIG/50002.

G 3.2.11 High-power variants of reed track circuits supply higher currents to the rail and are used in certain applications where a higher level of immunity is required. They incorporate an attenuator in the input to the receiver making them less susceptible to EMI than the standard type, and will therefore be compliant with the limits set out in Table *3*.

3.3 TI 21 / EBI Track 200 (AC lines)

3.3.1 TI 21 / EBI Track 200 track circuits (AC lines) - rail current

3.3.1.1 Double rail TI 21 / EBI Track 200 track circuits on an AC electrified line shall be capable of detecting rail vehicles in the presence of rail currents conducted by each train up to the values in each of the frequency bands set out in Table *4*, for a time exceeding 0.04 s.

TI 21 / EBI Track 200 channel	Centre frequency (Hz)	Operating frequency (Hz)	Maximum rail current (A RMS)
E	1549	1532	0.937
		1566	0.806
A	1699	1682	0.843
		1716	0.731
G	1848	1831	0.887
		1865	0.753
C	1996	1979	0.809
		2013	0.696
F	2146	2129	0.659
		2163	0.498
B	2296	2279	0.646
		2313	0.492
H	2445	2428	0.607
		2462	0.440
D	2593	2576	0.574
		2610	0.095

Table 4: Double rail TI 21 / EBI Track 200 limit for in-band frequencies - AC electrified lines

3.3.1.2 Single rail TI 21 / EBI Track 200 track circuits on an AC electrified line shall be capable of detecting rail vehicles in the presence of rail return currents emitted by each train up to the values in each of the frequency bands set out in Table 5 for a time exceeding 0.04 s.

TI 21 / EBI Track 200 channel	Centre frequency (Hz)	Operating frequency (Hz)	Maximum rail current (A RMS)
E	1549	1532	0.745
		1566	0.548
A	1699	1682	0.181
		1716	0.142
G	1848	1831	1.150
		1865	0.901
C	1996	1979	0.174
		2013	0.141
F	2146	2129	0.593
		2163	0.458
B	2296	2279	0.134
		2313	0.108
H	2445	2428	0.659
		2462	0.490
D	2593	2576	0.119
		2610	0.416

Table 5: Single rail TI 21 / EBI Track 200 limit for in-band frequencies - AC electrified lines

Rationale

G 3.3.1.3 EMC of TI 21 / EBI Track 200 track circuits with rail vehicles.

G 3.3.1.4 Excessive rail current can result in false operation of a frequency modulated track circuit or prevent its correct operation.

Guidance

G 3.3.1.5 Reliable operation of TI 21 / EBI Track 200 track circuits can be affected by EMI from trains which conduct currents within the track circuit operating frequency bands into the rails.

G 3.3.1.6 The specified current levels and the minimum time of 0.04 s are relevant to a right-side failure of a track circuit (track circuit showing occupied when clear). To cause a wrong-side failure (track circuit showing clear when occupied), current exceeding the specified limit would have to be present for 2 s and be modulated at the correct rate (between 3.36 Hz and 6.24 Hz) between the two operating frequencies.

G 3.3.1.7 Experience suggests that TI 21 / EBI Track 200 track circuits fitted with digital receivers are immune to common transients, including:

a) Inrush current up to 300 A.
b) Ice on the overhead line for line current of 300 A.
c) Pantograph bounce with 300 A traction current.
d) Circuit breaker opening with 300 A traction current.

G 3.3.1.8 The maximum current values set out in *Table 4* and *Table 5*:

a) Are applicable to analogue and digital receivers.
b) Include a 50 % apportionment to allow for other interference sources.
c) Are consistent with TS 50238-2:2015 section A.17, which includes only the lower value for each channel, and supersede the data set out in Network Rail document NR/GN/SIG/50008.

G 3.3.1.9 The maximum current values set out in Table *4* are based on the following modelling assumptions:

a) Maximum length 1100 m end fed or 2000 m centre fed.
b) Cross-bonding in accordance with applicable Network Rail standards.
c) Termination with either end termination units (ETUs) or tuning units (TUs).
d) Worst case return traction current imbalance across an ETU/TU in a double rail installation is 10 %.
e) B3 type impedance bonds.

G 3.3.1.10 The maximum current values set out in Table *5* are based on the following modelling assumptions:

a) Termination with either ETUs or track connection units (TCUs).
b) Maximum length 250 m with ETU or 200 m with TCU.
c) For configurations with ETUs, only frequencies A, B, C and D are used on single track or two-track lines.
d) Single rail track circuits using frequencies E, F, G and H on AC electrified lines are limited in length to provide higher levels of immunity, as these frequencies are close to odd harmonics of the 50 Hz traction supply and it is not practicable to design AC traction to avoid significant currents at these frequencies.

3.3.2 TI 21 / EBI Track 200 track circuits - bandwidth

3.3.2.1 Assessment of conformity of TI 21 / EBI Track 200 track circuits on AC electrified lines with the immunity limits set out in Table 4 and Table 5 shall be based on analysis of train emissions using a digital filter with a bandwidth of:

a) -3 dB at ± 6 Hz from centre frequency.
b) -20 dB at ± 30 Hz from centre frequency.

Rationale

G 3.3.2.2 The specified parameters of the filter provide a frequency response that is representative of the TI 21 and EBI Track 200 track circuit receivers.

Guidance

G 3.3.2.3 Train emissions are analysed using a defined filter characteristic for each of the TI 21 / EBI Track 200 track circuit operating frequencies to provide an indication of the predicted effect on the track circuit receivers.

G 3.3.2.4 Further details of the track circuit response are given in NR/GN/SIG/50008.

3.3.3 TI 21 / EBI Track 200 track circuits - immunity to 50 Hz harmonics

Guidance

G 3.3.3.1 Table 6 gives accepted limits for the susceptibility of TI 21 / EBI Track 200 track circuits to harmonics of 50 Hz mains frequencies. To assess train current against these susceptibility limits, the limit shown in the table for each 50 Hz harmonic can be compared with the root of sum of squares of the FFT of the traction current for all frequency bins between the lower frequency and upper frequency identified in the table, using a 1 Hz FFT with Hanning window and 50 % overlap.

Channel	50 Hz harmonic frequency Hz	Harmonic order	Lower frequency for analysis, Hz	Upper frequency for analysis, Hz	Double Rail per train limit, A	Single Rail per train limit, A
E	1500	30	1494	1506	6.351	6.212
	1550	31	1543	1557	0.892	0.698
	1600	32	1593	1607	6.916	2.531
A	1650	33	1643	1657	5.429	1.462
	1700	34	1693	1707	0.805	0.178
	1750	35	1743	1757	6.286	0.898

Channel	50 Hz harmonic frequency Hz	Harmonic order	Lower frequency for analysis, Hz	Upper frequency for analysis, Hz	Double Rail per train limit, A	Single Rail per train limit, A
G	1800	36	1792	1808	4.791	7.380
	1850	37	1842	1858	0.873	1.065
	1900	38	1892	1908	6.621	4.436
C	1950	39	1942	1958	3.807	1.075
	2000	40	1992	2008	0.805	0.151
	2050	41	2041	2059	7.296	1.101
F	2100	42	2091	2109	3.165	3.309
	2150	43	2141	2159	0.592	0.493
	2200	44	2191	2209	3.945	3.077
B	2250	45	2241	2259	3.062	0.744
	2300	46	2290	2310	0.585	0.111
	2350	47	2340	2360	3.755	0.638
H	2400	48	2390	2410	2.383	3.058
	2450	49	2440	2460	0.503	0.521
	2500	50	2490	2510	3.465	3.154
D	2550	51	2539	2561	1.630	0.480
	2600	52	2589	2611	0.416	0.094
	2650	53	2639	2661	4.699	0.783

Table 6: TI 21 / EBI Track 200 limits for mains harmonic frequencies

G 3.3.3.2 The analysis specified above will not resolve short duration exceedances. Exceedances of these limits for longer than 1 s may lead to a right-side failure (track circuit showing occupied when clear), but digital receivers have been proved to be immune to certain types of transient as stated in *G 3.3.1.7*.

3.3.4 TI 21 / EBI Track 200 track circuits - axle-to-axle voltage

3.3.4.1 Double rail TI 21 and EBI Track 200 track circuits on an AC electrified line shall be capable of detecting rail vehicles in the presence of axle-to-axle voltages introduced by each train up to 0.151 V in each of the frequency bands set out in Table 4.

3.3.4.2 Single rail TI 21 and EBI Track 200 track circuits on an AC electrified line shall be capable of detecting rail vehicles in the presence of axle-to-axle voltages introduced by each train up to 0.120 V in each of the frequency bands set out in Table 5.

Rationale

G 3.3.4.3 Excessive axle-to-axle voltages can result in false operation of a frequency modulated track circuit.

G 3.3.4.4 These limits are based on analysis of TI 21 / EBI Track 200 track circuits using frequencies A to D on a double track line.

Guidance

G 3.3.4.5 The limits are derived from analysis of a right-side failure scenario in which an interference voltage introduced into an unoccupied track section by a train on another section of track prevents energisation of the TI 21 / EBI Track 200 receiver, causing the track circuit to be shown as occupied. To cause a wrong-side failure (track circuit showing clear when occupied), an interference voltage would have to be present for at least 2 s and modulated at the correct rate between the two operating frequencies.

G 3.3.4.6 Frequencies E to H are only used where there are more than two tracks, and the additional parallel current paths available in this case means that immunity to longitudinal voltage will be higher than on a double track line.

Part 4 Track Circuits on DC Electrified Lines

4.1 50 Hz track circuits

4.1.1 50 Hz AC track circuits - steady state

4.1.1.1 50 Hz AC track circuits shall be capable of detecting rail vehicles in the presence of the levels of steady state EMI set out in Table 7, over the frequency range 48 Hz to 52 Hz.

Track circuit configuration	Maximum rail current (steady state) (per train)	Maximum axle-to-axle voltage (steady state)
Single rail	1.98 A	150 mV
Double rail	4.0 A	Not defined

Table 7: Compatibility limits for 50 Hz AC track circuits on DC electrified lines

Rationale

G 4.1.1.2 EMC of 50 Hz AC track circuits with rail vehicles.

G 4.1.1.3 Excessive rail current or AC axle-to-axle voltage can result in false operation of a 50 Hz AC track circuit.

G 4.1.1.4 The frequency range of 48 Hz to 52 Hz allows for variation in the frequency of the mains supply, which would allow the track relay to respond to interference voltages at these frequencies.

G 4.1.1.5 The limits represent one-third of the current that could operate a track relay, allowing for transmitter breakthrough and the presence of other trains.

Guidance

G 4.1.1.6 Reliable operation of 50 Hz AC track circuits can be adversely affected by EMI from trains, which conduct traction return currents into the rails and produce axle-to-axle voltages between the wheelsets. This can include loss of detection of a rail vehicle.

G 4.1.1.7

G 4.1.1.8 The operation of 50 Hz AC track circuits is also affected by the level of 50 Hz traction supply ripple voltage that can be conducted by the train. Recent EMC assessments have been made on the basis of a figure of 0.6 V RMS for traction supply ripple.

G 4.1.1.9 The limits for single rail track circuits set out in Table 7 are based on historical modelling described in Network Rail document NR/GN/SIG/50005, which assumed the following infrastructure configuration, representing the most susceptible conditions to EMI for intact infrastructure:

a) 750 V DC electrification.
b) Maximum length of single-rail 50 Hz track circuit is 200 m (although the limit may still be applicable to longer track circuits with additional cross-bonding).

c) Relay types - VT1, CE391 and G4.

G 4.1.1.10 The VT1(SP) configuration of 50 Hz track circuit uses a VT1 relay, but the installation and configuration was designed to offer greater immunity to higher levels of traction current.

G 4.1.1.11 The limits for double rail track circuits set out in Table 7 are based on historical modelling described in Network Rail document NR/SP/SIG/50006, which assumed the following infrastructure configuration, representing the most susceptible conditions to EMI for intact infrastructure:

a) 750 V DC electrification.
b) Maximum length of double-rail 50 Hz track circuit 1000 m (although the limit may still be applicable to longer track circuits with additional cross-bonding).
c) Maximum length of traction feeder section between substations 7.5 km.
d) Relay types - VT1, CE391 and G4.

G 4.1.1.12 Further detail of the modelling of AC 50 Hz track circuits is set out in Network Rail documents NR/GN/SIG/50005 and NR/SP/SIG/50006.

4.1.2 50 Hz AC track circuits - transients

Guidance

G 4.1.2.1 Transient currents passing into the rails can contain sufficient 50 Hz components to energise a 50 Hz track relay for a short period of time.

G 4.1.2.2 It is not practicable to specify a network-wide limit for transient 50 Hz interference. A single transient event is unlikely to energise a track relay for long enough to create a risk from incorrect clearance. However, in many cases (for example in conditions of intermittent contact between collector shoe and traction rail) transients can occur with sufficient regularity that a sequence of transients may be capable of energising the track relay for sufficient time to create a risk.

G 4.1.2.3 It is good practice to incorporate a time delay in the interface between 50 Hz track circuits and the interlocking to mitigate the effect of transients. Methods of achieving this include provision of a slow to operate follower relay or using an interlocking input that includes an inherent time delay.

G 4.1.2.4 The design of the traction current collection and control limits 50 Hz transients and reduces their effect on 50 Hz track circuits. Good practice in this area includes the following features:

a) The train shoe gear connected together by cables to form shoebuses.
b) Each shoebus fed by at least two shoes per train side.
c) Each shoebus to span the outer bogies of at least 2 x 20 m cars.
d) Maximum DC current per shoebus 3500 A for normal (undegraded) operation.
e) Line current controlled so that no change in tractive or braking effort results in a di/dt greater than that caused by gaps.

G 4.1.2.5 In the presence of infrastructure faults such as a broken rail, the susceptibility of 50 Hz track circuits is increased considerably, and absolute values of allowable 50 Hz currents would be unrealistically low. It is therefore not practicable to specify a network-wide limit for degraded infrastructure conditions. EMC between 50 Hz track circuits and rail vehicles in foreseeable degraded conditions is assessed as part of the route compatibility assessment.

4.2 Reed track circuits (DC lines)

4.2.1 Reed track circuits on DC electrified lines shall be capable of detecting rail vehicles in the presence of the EMI levels set out in Table 8.

Frequency		Maximum steady state rail current (per train)	Maximum steady state axle-to-axle voltage
Designation	Hz		
f211	363	195 mA	146 mV
f212	366		
f213	369		
f214	372		
f215	375		
f216	378		
f217	381		
f218	384		
f219	408		
f220	417		
f221	423		

Table 8: Compatibility limits for reed track circuits on DC electrified lines

4.2.2 Reed track circuits on DC electrified lines shall meet the values set out in Table 8 for a half-power (-3 dB) bandwidth of 0.5 Hz.

Rationale

G 4.2.3 EMC of reed track circuits with rail vehicles.

G 4.2.4 Excessive rail current or axle-to-axle voltage can result in false operation of a reed track circuit.

G 4.2.5 Reed track circuits are susceptible to interference at their operating frequency, which is a single unmodulated frequency determined by a narrow bandwidth mechanical reed filter. The specified bandwidth criteria represent the frequency response of the reed track circuit receiver.

Guidance

G 4.2.6 Reliable operation of reed track circuits can be affected by EMI from trains, which conduct traction return currents into the rails and produce axle-to-axle voltages between the wheelsets.

G 4.2.7 The limits set out in Table *8* are based on the historical modelling of a double rail reed track circuit assuming the following infrastructure configuration, which was assessed to represent the most susceptible conditions to EMI for intact infrastructure:

a) Reed track circuit in double rail mode.
b) DC electrified line.
c) Double track line.
d) Most sensitive receiver setting.
e) Maximum track circuit length 1200 m.

G 4.2.8 Further detail of the modelling is set out in Network Rail document NR/SP/SIG/50003.

G 4.2.9 Further details of the frequency response of the reed track circuit receiver are set out in Network Rail document NR/SP/SIG/50002.

G 4.2.10 NR/SP/SIG/50003 identifies a lower maximum rail current limit of 96 mA for reed track circuits on DC electrified lines, to allow for degraded infrastructure conditions. Consideration of the impact of infrastructure failures on EMC is part of the route compatibility assessment.

G 4.2.11 The analysis in NR/SP/SIG/50003 showed that the interference current limit for reed track circuit intermediate loop receivers in a worst case condition of infrastructure defects is 88 mA.

4.3 TI 21 / EBI Track 200 (DC lines)

4.3.1 TI 21 / EBI Track 200 track circuits (DC lines) - rail current

4.3.1.1 Double rail TI 21 / EBI Track 200 track circuits on DC electrified lines shall be capable of detecting rail vehicles in the presence of rail currents conducted by each train up to the values in each of the frequency bands set out in Table *9*, for a time exceeding 0.04 s.

TI 21 / EBI Track 200 channel	Centre frequency (Hz)	Operating frequency (Hz)	Maximum rail current (A RMS)
E	1549	1532	0.226
		1566	0.249

TI 21 / EBI Track 200 channel	Centre frequency (Hz)	Operating frequency (Hz)	Maximum rail current (A RMS)
A	1699	1682	0.178
		1716	0.202
G	1848	1831	0.189
		1865	0.219
C	1996	1979	0.157
		2013	0.182
F	2146	2129	0.228
		2163	0.262
B	2296	2279	0.237
		2313	0.264
H	2445	2428	0.225
		2462	0.247
D	2593	2576	0.23
		2610	0.264

Table 9: TI 21 / EBI Track 200 double rail or single rail limit for in-band frequencies - DC electrified lines

Rationale

G 4.3.1.2 EMC of TI 21 / EBI Track 200 track circuits with rail vehicles.

G 4.3.1.3 Excessive rail current can result in false operation of a frequency modulated track circuit.

Guidance

G 4.3.1.4 Reliable operation of TI 21 / EBI Track 200 track circuits can be affected by EMI from trains, which conduct currents within the track circuit operating frequency bands into the rails.

G 4.3.1.5 The specified current levels and minimum time of 0.04 s are relevant to a right-side failure of a track circuit (track circuit showing occupied when clear). To cause a wrong-side failure (track circuit showing clear when occupied), current exceeding the specified limit would have to be present for 2 s and be modulated at the correct rate between the two operating frequencies.

G 4.3.1.6 The maximum current values set out in Table 9:

a) Are applicable to analogue and digital receivers.
b) Are consistent with TS 50238-2:2015 section A.17 (although this includes only the lower value for each channel), and supersede the data set out in in Network Rail document NR/GN/SIG/50008.

G 4.3.1.7 The maximum current values set out in Table 9 are based on historical modelling assuming the following infrastructure configuration:

a) Maximum length 1100 m end fed or 2000 m centre fed.
b) Cross-bonding in accordance with applicable Network Rail standards.
c) Termination with either ETUs or TUs.
d) Worst case return traction current imbalance (100 %) across an ETU/TU in a double rail installation.

4.3.2 TI 21 / EBI Track 200 track circuits -bandwidth

4.3.2.1 Assessment of conformity of TI 21 / EBI Track 200 track circuits on DC electrified lines with the emission limits set out in Table 9 shall be based on analysis of train emissions using a digital filter with a bandwidth of:

a) -3 dB at ± 6 Hz from centre frequency.
b) -20 dB at ± 30 Hz from centre frequency.

Rationale

G 4.3.2.2 The specified parameters of the filter provide a frequency response that is representative of the TI 21 and EBI Track 200 track circuit receivers.

Guidance

G 4.3.2.3 Train emissions are analysed using a defined filter characteristic for each of the TI 21 / EBI Track 200 track circuit operating frequencies to provide an indication of the predicted effect on the track circuit receivers.

G 4.3.2.4 Further details of the track circuit response are given in Network Rail document NR/GN/SIG/50008.

4.4 FS2600 track circuits

4.4.1 FS2600 track circuits shall be capable of detecting rail vehicles in the presence of the EMI levels set out in Table 10 at the operating frequencies set out in Table 11.

Rail current (per train)	Axle-to-axle voltage
472 mA	369 mV

Table 10: Compatibility limits for FS2600 track circuits on DC electrified lines

Channel no.	Centre (carrier) frequency (Hz)	Lower frequency (Hz)	Upper frequency (Hz)
1	388.8	371.8	405.8
2	403.2	386.2	420.2
3	417.6	400.6	434.6
4	432.0	415.0	449.0
5	441.6	424.6	458.6
6	456.0	439.0	473.0
7	470.4	453.4	487.4
8	484.8	467.8	501.8
9	494.4	477.4	511.4
10	508.8	491.8	525.8

Table 11: FS2600 operating frequencies

Rationale

G 4.4.2 EMC of FS2600 track circuits with rail vehicles.

G 4.4.3 Excessive rail current or axle-to-axle voltage can result in false operation of a FS2600 track circuit.

Guidance

G 4.4.4 FS2600 track circuit receivers respond only to a correctly coded signal carrying a valid pair of frequencies. For an interference signal to falsely energise an FS2600 receiver, leading to loss of detection when the section is occupied, the signal has to be present for at least 944 ms and correctly coded. It is unlikely that train-generated interference will produce a correctly coded signal; however, a signal in the frequency range of the receiver which does not have correct coding can cause a right-side failure (de-energisation of a receiver in an adjacent track section which is not occupied by a train).

G 4.4.5 The digital sampling process of the FS2600 receiver analyses the received signal in bands of 4.8 Hz, and therefore responds to a signal within 2.4 Hz of the nominal frequency.

G 4.4.6 The limits set out in Table *10* are based on the historical modelling of an FS2600 track circuit, which assumed the following infrastructure configuration, which represents the most susceptible conditions to EMI with effectively bonded infrastructure:

a) Double track.
b) Jointed track.
c) 750 V DC third rail electrification.
d) Traction return via running rails.
e) Track circuit maximum length 1200 m.
f) Track circuit installed in double rail mode.
g) Train occupying FS2600 track circuit channel 10 (508.8 Hz); the adjacent track circuit is channel 1.
h) Track circuit receiver at highest gain setting.
i) Train interference limit for intact infrastructure is one-third of total interference budget.

G 4.4.7 Further detail of the modelling is set out in Network Rail document NR/GN/SIG/50009.

Part 5 Track Circuits Used on Both AC and DC Electrified Lines

5.1 EBI Track 400

5.1.1 EBI Track 400 track circuits - rail current

5.1.1.1 EBI Track 400 ‘open line’ track circuits shall be capable of detecting rail vehicles in the presence of rail currents conducted by each train up to the values at each of the frequencies set out in Table *12*.

Channel	Centre frequency (Hz)	Maximum rail current (steady state) (A RMS)	
		Double rail	Single rail
E	1549	0.953	0.098 #
A	1699	0.936	0.099
G	1848	0.81	0.091 #
C	1996	0.778	0.087
F	2146	0.663	0.072 #
B	2296	0.628	0.069
H	2445	0.545	0.061 #
D	2593	0.547	0.063

Table 12: EBI Track 400 mainline (open line) - worst case centre frequency interference limit

Note: frequencies E, F, G and H are not currently used in single rail form on AC electrified lines because these frequencies are close to odd harmonics of the 50 Hz supply.

5.1.1.2 EBI Track 400 ‘station area’ double rail track circuits shall be capable of detecting the rail vehicles in the presence of rail currents conducted by each train up to the values at each of the frequencies set out in Table *13*.

Channel	Centre frequency (Hz)	Maximum rail current (steady state) (A RMS)
F5	5700	1.081
F1	6100	1.073

Channel	Centre frequency (Hz)	Maximum rail current (steady state) (A RMS)
F7	6500	1.052
F3	6900	1.062
F6	7300	1.046
F2	7700	1.058
F8	8100	1.053
F4	8500	1.149

Table 13: EBI Track 400 station area - centre frequency interference limit

Rationale

G 5.1.1.3 EMC of EBI Track 400 track circuits with rail vehicles.

G 5.1.1.4 Excessive rail current can result in false operation of a frequency modulated track circuit.

Guidance

G 5.1.1.5 Reliable operation of EBI Track 400 track circuits can be affected by EMI from trains, which conduct currents within the track circuit operating frequency bands into the rails.

G 5.1.1.6 For EBI Track 400 track circuits any credible false operation will result in right-side failure (track circuit showing occupied when clear). The secure coding of the track circuit means that there is no credible scenario in which excessive rail current will cause a wrong-side failure (track circuit showing clear when occupied).

G 5.1.1.7 The maximum current values set out in Table 12 and Table 13 are taken from the EBI Track 400 EMC Acceptance Case For Network Rail Infrastructure (Bombardier document reference TR580098959A4-03). The values set out in Table 12 are based on a maximum length of 1100 m for double rail track circuits and 200 m for single rail track circuits. The values set out in Table 13 are based on a maximum length of 350 m for double rail 'station area' track circuits.

G 5.1.1.8 EBI Track 400 'station area' track circuits are not currently used in single rail form.

5.1.2 EBI Track 400 track circuits - FFT analysis

5.1.2.1 Assessment of conformity of EBI Track 400 track circuits with the immunity limits set out in Table 12 and Table 13 shall be based on analysis of train emissions using peak hold values from a 1 Hz FFT with 50 % overlap.

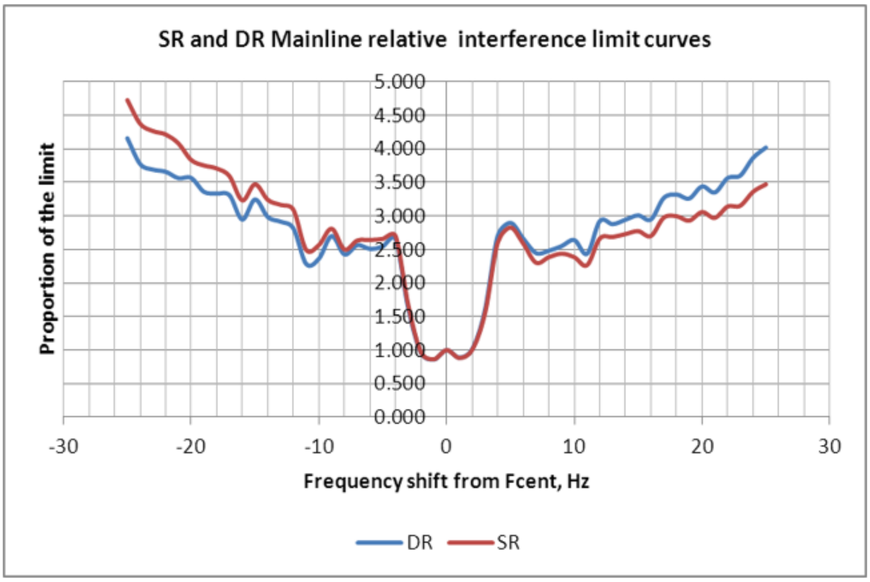
Rationale

G 5.1.2.2 The specified parameters for the digital filter used in the FFT analysis represent the frequency response of the EBI Track 400 track circuit receivers.

Guidance

G 5.1.2.3 Train emissions are analysed using a defined filter characteristic for each of the EBI Track 400 track circuit operating frequencies to provide an indication of the predicted effect on the track circuit receivers.

G 5.1.2.4 The FFT output is compared bin by bin with the frequency response curves of EBI Track 400 track circuits shown in Figure 1 and Figure 2, scaled for the specific track circuit using the frequencies and levels defined in Table 12 and Table 13.



DR = Double Rail, SR = Single Rail

Figure 1: Normalised frequency response curve of EBI Track 400 'open line' track circuit

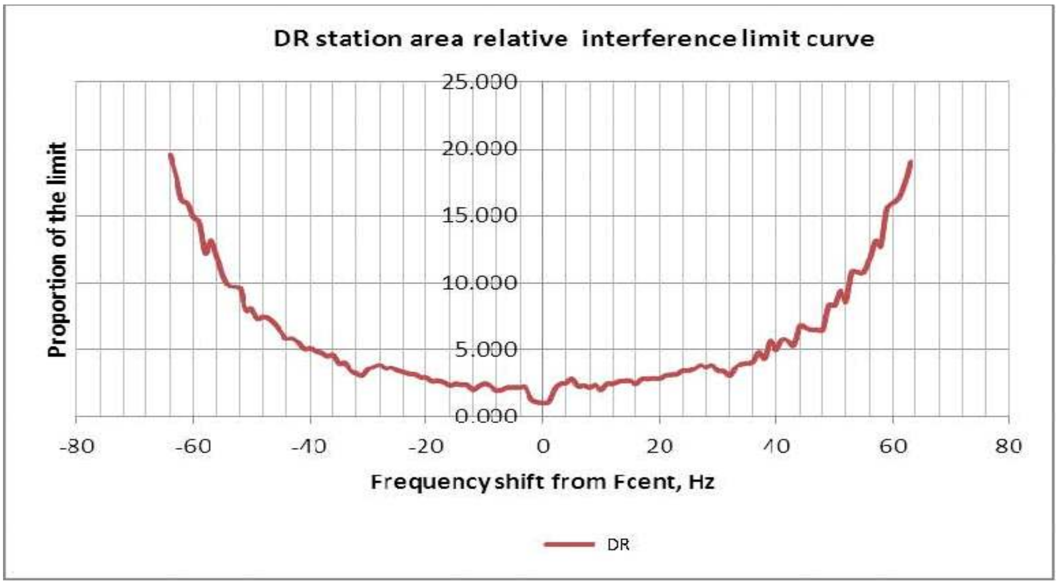


Figure 2: Normalised frequency response curve of EBI Track 400 'station area' track circuit

5.1.3 EBI Track 400 track circuits - axle-to-axle voltage

Guidance

G 5.1.3.1 Accepted limits for longitudinal (axle-to-axle) voltage for EBI Track 400 Open Line track circuits are shown in *Table 14* and *Table 15*.

G 5.1.3.2 These limits only cover channels A-D because it is expected that these will be the most vulnerable to longitudinal voltage due to their use on double track lines. If the same values are used for channels E-H in multiple track areas they will be pessimistic.

Frequency channel of the victim track circuit	Channel of the track circuit with train generating V_{aa}	Frequency spectrum, Hz	Double Rail V_{aa} limit, V with 50% margin
A	C or D	1699 ± 5	0.607
B	C or D	1996 ± 5	0.634
C	A or B	2296 ± 5	0.577
D	A or B	2593 ± 5	0.525

Table 14: EBI Track 400 Open Line: axle-to-axle voltage (V_{aa}) limits for victim double rail track circuit, the adjacent track also fitted with double rail EBI Track 400 Open Line

Frequency channel	Frequency spectrum, Hz	Double Rail V_{aa} limit, V with 50% margin	Single Rail V_{aa} limit, V with 50% margin
A	1699 ± 5	0.591	0.110
B	1996 ± 5	0.621	0.123
C	2296 ± 5	0.568	0.098
D	2593 ± 5	0.518	0092

Table 15: EBI Track 400 Open Line: axle-to-axle voltage (V_{aa}) limits for victim single rail and double rail circuit, the adjacent track with any other track circuit

G 5.1.3.3 Accepted limits for longitudinal (axle-to-axle) voltage for EBI Track 400 Station Area track circuits are shown in *Table 16* and *Table 17*.

Frequency channel of the victim track circuit	Channel of the track circuit with train generating V_{aa}	Frequency spectrum, Hz	Double Rail V_{aa} limit, V with 50% margin
F1	F5 or F6	6100 ± 40	1.535
F2	F5 or F6	7700 ± 40	1.924
F5	F1 or F2	5700 ± 40	1.440
F6	F1 or F2	7300 ± 408	1.807

Table 16: EBI Track 400 Station Area: axle-to-axle voltage (V_{aa}) limits for victim double rail track circuit, the adjacent track also fitted with double rail EBI Track 400 Station Area

Frequency channel	Frequency spectrum, Hz	Double Rail V_{aa} limit, V with 50% margin
F1	6100 ± 40	1.532
F2	7700 ± 40	1.921
F5	5700 ± 40	1.722

Frequency channel	Frequency spectrum, Hz	Double Rail V_{aa} limit, V with 50% margin
F6	7300 ± 408	2.332

Table 17: EBI Track 400 Station Area: axle-to-axle voltage (V_{aa}) limits for victim single rail and double rail track circuit, the adjacent track with any other track circuit

5.2 HVI track circuits

Guidance

G 5.2.1 Asymmetric current impulses of sufficient magnitude could energise an HVI track circuit relay when a train is occupying the track section.

G 5.2.2 Due to the nature of the waveform used by the HVI track circuits, the susceptibility criteria for compatibility cannot be expressed as a simple emission level at a particular frequency or range of frequencies.

G 5.2.3 NR/GN/SIG/50007, section 5.4, sets out parameters of asymmetric waveforms as selection criteria to identify waveforms contained in train emissions that should be analysed in detail to assess compatibility (for example by inputting them into an appropriate model), but these are not specified as actual operating limits.

G 5.2.4 The characteristics identified in NR/GN/SIG/50007 are:

a) di/dt exceeding 114 A/ms measured between samples 800 μs apart.
b) Asymmetry > 0.1, where asymmetry is defined as ABS[(I+ + I-)/(I+ – I-)], I+ and I- are the local maximum and minimum of the current waveform within 100 ms of the point of maximum di/dt.

G 5.2.5 There is no specified limit on axle-to-axle voltage for HVI track circuits as they are not susceptible to realistically expected levels of axle-to-axle voltage.

Part 6 Track Circuits on Non-Electrified Lines

6.1 Track circuits used on non-electrified lines

Guidance

G 6.1.1 The types of track circuit used on electrified lines can also be used on non-electrified lines where immunity to EMI is necessary, for example near an electrified line or in the proximity of other rail systems such as metro or light rail lines. The limits set out in Parts 3, 4 and 5 are applicable.

G 6.1.2 Table 18, which is taken from Appendix D of NR/L2/SIG/50010, shows axle-to-axle voltage limits for other non-preferred types of track circuit used on non-electrified lines.

Train detection system	Frequency range of susceptibility	Steady state limits		Short term limits (pulse interference)	
		Margin	Limit	Margin	Limit
DC track circuits (non-AC immune)	DC	50 %	53 mV	20 %	80 mV.s*
	50 Hz	50 %	8.14 V		
	<20 Hz	50 %	See NR/L2/ SIG/ 50010 Fig.1 **		
Aster	1665 - 1735 Hz	50 %	16 mV	50 %	16 mV**
	1965 - 2035 Hz				
	2265 - 2335 Hz				
	2565 - 2665 Hz				
Western Region QR track circuits (white, and yellow with smoothing capacitor)	1 Hz to 1 kHz roll-off: 20 dB/dec	50 %	408 mV	20 %	40 mV.s

Train detection system	**Frequency range of susceptibility**	**Steady state limits**		**Short term limits (pulse interference)**	
		Margin	**Limit**	**Margin**	**Limit**
Western Region QR track circuits (blue)	1 Hz to 5 kHz roll-off: 5 dB/dec	50 %	559 mV	20 %	40 mV.s
Western Region QR track circuits (yellow, no smoothing capacitor)	1 Hz to 8 kHz roll-off: 5 dB/dec	50 %	702 mV	20 %	20 mV.s
Lucas	>20 kHz	N/A	Compatibility tests required for interference sources higher than 10 V rms	N/A	DC pulse with repetitive rate > 1 kHz: 0.028 V.s
Reed Jointless track circuits	363 Hz - 423 Hz	50 %	201 mV		See NR/L2/ SIG/ 50010 Fig. 18:
					> 1 s duration 100 mV.s *
Overlay track circuits	5 kHz - 100 kHz	N/A 50 % of applied axle-to-axle voltage results in interference voltage by definition	1.92 V		Note ** for < 1 s duration
					> 1 s duration: 100 mV.s *

Train detection system	Frequency range of susceptibility	Steady state limits		Short term limits (pulse interference)	
		Margin	Limit	Margin	Limit
Diode track circuit	DC	50 %	0.54 V		N/A
	DC to 13.7 Hz	50 %	See NR/L2/ SIG/ 50010 Fig. 26		
	13.7 Hz - 100 kHz***	50 %	17.5 V		
Coded track circuit	0.5 Hz - 10 Hz	50 % Compatibility tests required for interference sources >10 Hz	0.15 V		N/A
50 Hz track circuits	48 Hz - 52 Hz	50 %	225 mV		NR/SP/SIG/ 50006, NR/GN/SIG/ 50005

Table 18: Compatibility limits for track circuits on non-electrified lines

Notes:

* Impulse interference limits applicable to BR938 relays

** Risk assessment required to address potential intermittent false operation

*** Characteristics of BR966 F2 relay

Definitions

AC	Alternating Current.
Axle Counter System	A type of train detection system in which track-mounted equipment counts axles entering and leaving a track section at each extremity. This information is evaluated to determine whether the track section is occupied or clear.
Axle-to-axle voltage	Voltage generated by a train and appearing between any two axles of the train
CCT	Control-Command and Signalling (CCS) trackside subsystem.
DC	Direct Current.
Double rail track circuit	A track circuit where both rails are electrically separated from the adjacent track circuit, either using insulated rail joints or a tuned zone
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.
ETU	(TI 21 / EBI Track track circuit) End termination unit.
Fast Fourier Transform (FFT)	An algorithm used in signal processing to convert a signal from time domain to frequency domain.
HVI	High voltage impulse (type of track circuit).
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.
Single rail track circuit	A track circuit where only one rail is electrically separated from the adjacent track circuit using an insulated rail joint. The other rail is electrically continuous for traction return purposes.
TCU	(TI 21 / EBI Track track circuit) Track connection unit.
Track circuit	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.
Train	A train is defined as (a) traction unit(s) with or without coupled railway vehicles, including light locomotive and self-propelled rail vehicle operating in rail mode, with train data available operating between two or more defined points.
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*

Transmitter breakthrough	A voltage or current originating from the transmitter / feed of one train detection section, which is detectable by a track circuit relay / receiver of a different train detection section.
TSI	Technical Specification for Interoperability.
TTU	(TI 21 / EBI Track track circuit) Track tuning unit.

References

The Catalogue of Railway Group Standards gives the current issue number and status of documents published by RSSB. This information is also available from http://www.rssb.co.uk/railway-group-standards.co.uk.

RGSC 01	Railway Group Standards Code
RGSC 02	Standards Manual

Documents referenced in the text

Rail Industry Standards

RIS-8270-RST	Route Level Assessment of Technical Compatibility between Vehicles and Infrastructure (Will replace GERT8270: Assessment of Route Compatibility of Vehicles and Infrastructure)

Other references

BR938 Specification for Miniature Tractive Armature DC Neutral Track Relay, Plug-in Type for Railway Signalling Purposes

BR939A Specification for Miniature Tractive Armature AC Immune DC Neutral Track Relay, Plug-in Type for Railway Signalling Purposes

BR966 F2 AC Immune DC Neutral Track Relay

BR966 F9 AC Immune DC Neutral Track Relay

BS 1659:1950 Specification for tractive armature direct current neutral track and line relays for railway signalling

BS EN 50238:2003 Railway applications. Compatibility between rolling stock and train detection systems

BS EN 50617-1:2015 Railway applications. Technical parameters of train detection systems for the interoperability of the trans-European railway system. Track circuits

BS EN 50617-2:2015 Railway Applications. Technical parameters of train detection systems for the interoperability of the trans-European railway system. Axle counters

CLC/TS 50238-2:2015 Railway applications. Compatibility between rolling stock and train detection systems. Compatibility with track circuits

CLC/TS 50238-3:2013 Railway applications. Compatibility between rolling stock and train detection systems. Compatibility with axle counters

NR/GN/SIG/50005 Methodology for the demonstration of compatibility with 50 Hz Single Rail Track Circuits

NR/GN/SIG/50007 Methodology for the Demonstration of Compatibility with HVI Track Circuits

NR/GN/SIG/50008 Methodology for the demonstration of compatibility with TI 21 Track Circuits

NR/GN/SIG/50009 Methodology for the demonstration of compatibility with FS2600 Track Circuits

NR/L2/SIG/50010 Methodology for the demonstration of compatibility with train detection systems in use on non-electrified lines

NR/SP/SIG/50002 Methodology for the demonstration of compliance with Single Rail Reed Track Circuits on the AC railway

NR/SP/SIG/50003 Methodology for the demonstration of compliance with Double Rail Reed Track Circuits on the DC railway

NR/SP/SIG/50004 Methodology for the demonstration of electrical compatibility with DC (AC-immune) Track Circuits

NR/SP/SIG/50006 Methodology for the demonstration of compatibility with 50 Hz Double Rail Track Circuits

NR/SP/SIG/50011 Methodology for the demonstration of electrical compatibility with axle counters

TR580098959A4-03 (Bombardier): EBI Track 400 EMC Acceptance Case For Network Rail Infrastructure