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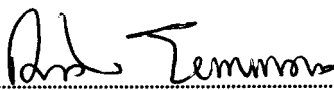
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Date	April 2006

Business Process Document

Methodology for the Demonstration of Electrical Compatibility with DC (AC Immune) Track Circuits

Endorsement & Authorisation

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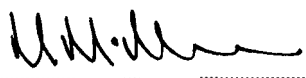
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Implementation

This business specification is for the guidance of all persons who are responsible for the production, submission and review of EMC safety cases for Network Rail SRP.

Compliance

This Network Rail Specification is mandatory and must be complied with by all parties seeking acceptance from the date of issue.

When this Specification is implemented, it is permissible for all projects, which have formally completed GRIP Level 4, to continue to comply with the Issue of any relevant Network Rail Standards current when GRIP Level 4 was reached and not to comply with requirements contained herein unless the designated [Standard Owner] has stipulated otherwise in the accompanying Briefing Note.

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I Purpose

The purpose of this document is to provide a methodology to demonstrate compatibility with a.c. immune d.c. track circuits on the a.c. railway on Network Rail Controlled Infrastructure. This is achieved by:

- providing a set of standard d.c. interference current limits for steady state interference;
- providing a set of d.c. interference voltage limits for steady state axle to axle interference;
- providing a methodology to determine whether low frequency or transient interference will falsely operate a d.c. track relay.

These standard limits and methodologies will facilitate the demonstration of compatibility with d.c. track circuits for rolling stock, as part of a Route Acceptance Safety Case.

2 Scope

This document covers a.c. immune d.c. track circuits installed in single rail mode on a.c. electrified Network Rail Controlled Infrastructure.

The methodology considers both intact and faulty infrastructure. Limits are established for both continuous welded rail (CWR) and jointed rail (JR) track types.

The maximum permissible levels (i.e. the limits) of d.c. interference current in the tracks which will not cause a wrong side failure (WSF) (i.e. false operation of the relay), have been derived. The levels account for multiple trains, transmitter breakthrough and include an appropriate safety margin.

Standard train current and axle to axle voltage steady state limits are defined for the types of a.c. immune d.c. track relay currently in use.

3 Reference documentation

3.1 Railway Group Standards

- [GK/RT0011](#) "Train Detection", Issue 3, August 2000
[GK/GN0611](#) "Train Detection", Issue 1, August 2000

3.2 Other Standards

- [RT/E/S/11752](#) "Train Detection", Issue 2, August 2001
[RT/E/PS/11755](#) "D.C. Track Circuits", Issue 1, December 2000
[RT/E/S/21078](#) "Design of Return Conductor Systems for A.C. Electrified Lines", Issue 1, March 1998
[RT/E/S/21085](#) "Design of Earthing and Bonding Systems for 25kV Electrified Lines", Issue 1, October 1998

- [BS IEC 61508](#) Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems, January 2001
- [BS EN 50238](#) "Compatibility between Rolling Stock and Train Detection Systems", February 2003

3.3 Previous Safety Case Documentation

- [DR0457 \[AEAT Rail\]](#) "Class 92 Locomotive EMC Safety Assessment Volume 2- DC Track Circuits", AEA Technology Report, Version D0, June 2000
- [STG-D-EPS\(373\)-RP-29 \[AEAT Rail\]](#) "Class 373 Support – Reed Track Circuits Infrastructure Modifications for Increased Immunity", Issue 1.1, March 1997
- [LR ES 009 \[BRR\]](#) "AC Immune d.c. Track Relay Tests", December 1993
- [STG-D-RFD\(092\)-RP-8 \[BRR\]](#) "DC Track Circuit Relays, Static Tests", Issue 1, August 1995
- [C2180-1 \[WSAR\]](#) "Characterisation of DC Track Relays (Report 98097) – Normalisation of Frequency Response Results", 14/9/98
- [3EER300002-1771 \[Bombardier Transportation\]](#) "Response to 50 Hz of DC Track Circuit Relays", Technical Report, 3/7/01

3.4 Other Documents

- [BR939A](#) "Specification for miniature tractive armature AC immune DC neutral track relay, plug-in type for railway signalling purposes", September 1971
- [BR966](#) "Specification for miniature tractive armature relays, plug-in type for railway signalling purposes", August 1981
- [BR933A](#) "Specification for miniature tractive armature AC immune DC slow pick-up neutral line relay, plug-in type for railway signalling purposes", September 1971
- [5025773-L-TR-002 \[WSAR\]](#) "Interference Limits for DC Track Circuits (AC Immune): Modelling Results", Issue 1.0, 27/4/04
- [LRDA40278/124/93003 \[AEAT Rail\]](#) "Apportioned Interference Current Limits For DC Track Circuits (AC Immune)," 9 August 2004
- [5025773-L-TR-001 \[WSAR\]](#) "Validation of Model For Use in Deriving Interference Limits for DC Track Circuits (AC Immune)," Issue 1.0, 24/06/04
- [10150.1238 \[Alstom Transport\]](#) "DC Track Circuit Risk Assessment", Rev.B, 26/04/02

4 D.C. Track Circuit Background

4.1 D.C. Track Circuit Operation

D.C. track circuits provide a simple and reliable track circuit for use on non d.c. electrified lines. In their basic form, power is applied to the rails at one end of the section and is transmitted via the rails to the d.c. track relay at the other end.

Two principal installation configurations are employed – double rail, where both rails are fitted with IRJs (Insulated Rail Joints) at each end of the section to keep adjacent track circuits electrically separate, and single rail, where only one of the rails is fitted with IRJs at each end of the section, and the other rail is thus electrically common with the adjacent track circuit. To permit the flow of traction return current, d.c. track circuits on a.c. electrified lines are exclusively of the single rail type.

The d.c. power supply is obtained from a transformer/rectifier or a battery, and is connected through a feed resistor to the rails. This resistor limits the current drawn from the power supply when the track circuit is shunted by the train, and permits the track circuit sensitivity to be adjusted. The performance of d.c. track circuits is determined by:

- the shunt resistance presented by the train;
- the drop away rail voltage (to tolerate d.c. interference and rail contamination);
- the minimum ballast resistance at which the track circuit remains functional;
- the need, or otherwise, for a.c. immunity.

In a.c. electrified areas, a.c. immunity is aided by connecting a choke at the feed end of the circuit, whilst the track relay itself is fitted with a magnetic slug to reduce its sensitivity to a.c. magnetisation.

A number of variants of d.c. track circuit have been employed over the years, each having different electrical parameters. However, of particular interest in determining permissible interference levels, are the relay characteristics. Available data for various relay types are provided in Table 2, in section 5.1 below.

The improved shunt characteristic of track circuits fitted with feed-end relays is not specifically modelled in this document. However, the effect of fitting a feed-end relay (a second relay at the feed end of the track circuit) is to reduce the susceptibility of the track circuit - it cannot increase its susceptibility.

The contacts of the two relays are connected such that whichever one responds first, it acts on the interlocking to register the state of the section. The analysis in this document, which accounts for the standard single relay arrangement, also encompasses those track circuits fitted with feed end relays.

Detailed descriptions of d.c. track circuits and their operation and installation are given in Network Rail Line Product Specification [\[RT/E/PS/11755\]](#).

4.2 Interference with D.C. Track Circuits

The main interference mechanism is where the d.c. content of the a.c. traction return current produces a voltage drop across the track relay by virtue of the train shunt (see Figure 1). To create the hazard from an a.c. current, the d.c. component of the traction current that flows in the rails must develop at least the drop-away voltage of the relay over the length of track between the train and the track circuit relay.

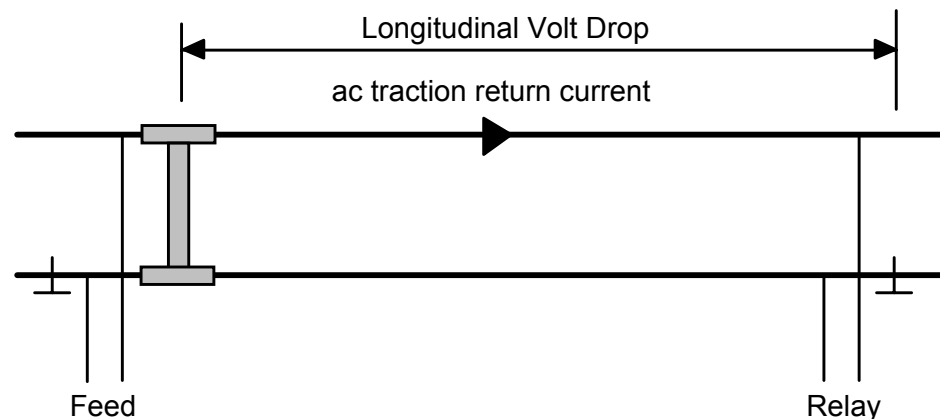


Figure 1: Single Rail D.C. Track Circuit in A.C. Electrified Areas

Thus the main factors to be considered, when assessing the susceptibility of a d.c. track circuit system, are:

- the sensitivity of the track circuit relay, which depends on the type of relay;
- track resistance per unit length, which depends on the type of track (CWR or JR) and the track layout;
- the effective length of the return path (track circuit length, plus any run round path due to faults).

As the susceptibility level is affected by any and all of these factors, it may prove unreasonable to consider the “worst case” (i.e. the most sensitive track relay and the longest track circuit on the highest-resistance track) as the generally applicable limit, as this may be significantly worse than that applicable to any individual track circuit on a given route.

A more reasonable approach is therefore to consider the actual lengths of the track circuits utilising the most sensitive relays that are present, and if they are on jointed track. If it is found that they do not appear on jointed track, or are less than the maximum recommended length, the appropriate limits can be set that will be more realistic for a particular route.

Conversely it may be found that track circuits longer than the maximum recommended length [\[RT/E/PS/11755\]](#) (if they are present on jointed track) may reduce limits to very low levels. Absolute compatibility with such circuits may be difficult to achieve and in

these cases arguments may need to be developed in accordance with section 9.1, below.

The influence of infrastructure faults (a break in the traction return rail, or a fault electrically equivalent to that), which increase the effective length of traction return path, must also be considered.

The contribution of other trains in the vicinity to the interference current is allowed for in the modelling along with a 20% safety margin, so the limits can be considered as the appropriate per train limits.

5 Derivation of Limits (Steady State)

The limits for d.c. and low frequency interference on the a.c. electrified railway have been calculated in ref. [5025773-L-TR-002] & [LRDA40278/124/93003]. These limits were calculated using the validated model [5025773-L-TR-001]. The model considered the effects of multiple trains, by first investigating the worst case positions of up to three trains. Once these worst case positions had been established, the model was run with the trains in these positions, as indicated in Figure 2. The full list of parameters and assumptions used in the model can be found in Appendices A and B.

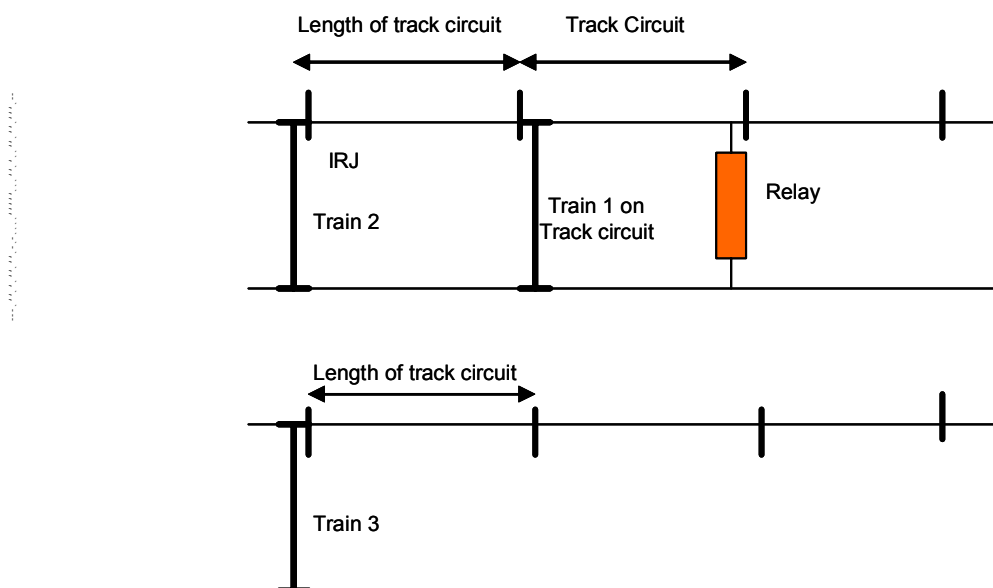


Figure 2 – Worst Case Positions for the Three Train Modelling - Double Track

For the double track scenarios, calculations were made for the following conditions:

- current for three trains (in established worst case positions) set to 0.1 mA
- current for three trains (in established worst case positions) set to 1 A
- current for a single train on the track circuit set to 1 A.

The results of the modelling are recorded in section 3.2 of [5025773-L-TR-002] for the above conditions, leading to the resultant voltage across the track circuit relay in mV. The three conditions above represent no train, multiple train and single train values of voltage across the relay V1, V2 and V3 in [5025773-L-TR-002]. The no train value (the model could not be run with train current of zero, so a nominal very low value of 0.1 mA was used), represents the transmitter breakthrough voltage of the track circuit. Hence:

- V1 represents the no train (transmitter breakthrough voltage)
- V2 is the three train value (the mV value of voltage across the relay)
- V3 is the one train value (the mV value of voltage across the relay)

The models were run a number of times to represent intact and failed infrastructure conditions and for each of the track circuit types that are present on Network Rail, primarily driven by the different relay types (see section 5.1). The infrastructure values and assumptions as detailed in Appendix B were used in the models and specific infrastructure scenarios were individually modelled as defined in section 5.2 and 5.3, below.

For single track scenarios the same process was followed, but with only two trains instead of three for the multiple train condition.

5.1 Relay Types

Eight different a.c. immune d.c. track relay types, which account for the majority of those in use, have been considered. Table 2 below summarises key data for these relay types. Specified values are given based on the parameters given in the relay specifications, or lowest measured values, where specifications are not available.

It should be noted that BR939A, BR966F2, and BR966F9 are examples of relay specification numbers. In addition to these numbers, manufacturers may also have their own unique part number. This can cause confusion where route surveys derived from Network Rail's assets register include a variety of different relay numbers that may be referring to the same type of relay. For example, relays are often listed in the assets register by specification type e.g. BR939 and sometimes by manufacturers part number e.g. QTA1 (which is a Westinghouse part number for a relay built to either BR939 or BR966F2 specification).

Examples of known manufacturer's part numbers built to specifications BR939 and BR966 are:

- QTA1 (Westinghouse)
- QTA2 (Westinghouse)
- ZA0051 (GEC)

Similarly one of the older relay types identified as a D6 (built by Westinghouse) also appears as a Field and Grant manufactured relay with the following identification:

- G3 (Field and Grant, built to the same specification as the D6 relay)

Another older type of relay known most commonly known as the BI has also been identified as follows:

- F15 (a version of the B1 type of relay built to specification F153925-B1)

The B2 type relay has also been quoted in documentation, but this is not a track circuit relay and does not therefore need to be considered.

Table 2 below can be taken to cover all known relay types on Network Rail. It represents the results of several significant studies carried out by three major organisations (AEA Technology, Atkins Rail and Bombardier Transportation) over recent years [[LR ES 009](#)], [[STG-D-RFD\(092\)-RP-8](#)], [[C2180-I](#)], and [[3EER300002-1771](#)]. This is a reasonable assumption since all apparent anomalies have been confirmed to represent examples of the different identifications described above.

Also, as stated in the assumptions in Appendix B, all relays built to BR939 and BR966 specifications are assumed to have similar characteristics. This is a reasonable assumption based on the evidence of the surveys [[LR ES 009](#)], [[STG-D-RFD\(092\)-RP-8](#)], [[C2180-I](#)], and [[3EER300002-1771](#)].

Relay Type	Nominal Coil Resistance	Minimum Drop-Away Voltage	Minimum Pick-Up Voltage	Maximum Length of Track Circuit (metres) *
BR939A	20Ω	1.100 V	1.620 V	1000
BR966 F2	9Ω	0.730 V	1.080 V	680
BR966 F9	60Ω	1.900 V	2.800 V	350
B1	9Ω	0.531 V	0.740 V	600
CAA02	9Ω	0.470 V	0.710 V	600
NT2A	9Ω	0.469 V	0.600 V	600
D6	9Ω	0.427 V	0.550 V	600
CAA04	9Ω	0.290 V	0.440 V	600

* Maximum track circuit lengths are as proposed in RT/E/PS/11755, however longer lengths may exist

Table 2 – D.C. Track Relay Characteristics

The most sensitive d.c. track relay which is used in a.c. electrified areas is the CAA04, which has a minimum specified drop-away voltage of 0.29V. The CAA04 is however a slow to pick relay compared to BR939 and BR966, which are both much faster to respond.

The mV/A values across the relays determined from the modelling [[5025773-L-TR-002](#)] have been converted into permitted train current limits. This calculation takes into account the transmitter breakthrough voltage, multiple trains and includes an additional 20% safety margin. Therefore no further margin is required.

All the calculations assume multiple trains as this represents a worst case. The results of the calculations presented in [\[LRDA40278/124/93003\]](#) are given in section 5.2 & 5.3.

As stated in Table 2, the maximum track circuit lengths quoted are based on the maximum recommended lengths in Network Rail Company Standard [\[RT/E/PS/11755\]](#). Longer lengths than these may exist on specific routes. If present, these longer track circuits would need to be considered and appropriate ALARP arguments developed if absolute compatibility cannot be demonstrated.

5.2 Single Track Railway: Intact and Failed Infrastructure

For a single track railway (with no cross bonding present) the analysis presented in ref. [\[5025773-L-TR-002\]](#) & [\[LRDA40278/124/93003\]](#) is summarised in Tables 3, 4, 5 and 6.

The calculations carried out by each of the four models are detailed below:

- DCMOD13a: single track railway, jointed rail, booster sections with return conductor.
- DCMOD15a: single track railway, CWR, booster sections with return conductor.
- DCMOD17a: single track railway, jointed rail with rail return and earth-wire.
- DCMOD19a: single track railway, CWR with rail return and earth-wire.

Each of the four models has been used to calculate limits for both intact infrastructure and failed infrastructure.

Relay Type	Relay Coil Resistance (Ω)	Drop Away Voltage (V)	Permissible Train Current Limit for Maximum Line Standard Track Circuit Length (A)	
			Failed Infrastructure	Intact Infrastructure
BR939A	20	1.100	0.93	7.29
BR966 F2	9	0.730	0.62	6.69
BR966 F9	60	1.900	1.43	25.44
BI	9	0.531	0.44	5.07
CAA02	9	0.470	0.39	4.46
NT2A	9	0.469	0.38	4.45
D6	9	0.427	0.35	4.03
CAA04	9	0.290	0.23	2.66

Table 3 – Model 13a - Single Track (Jointed Rail, Booster Sections, Return Conductor) Calculated Permissible Interference Current

Relay Type	Relay Coil Resistance (Ω)	Drop Away Voltage (V)	Permissible Train Current Limit for Maximum Line Standard Track Circuit Length (A)	
			Failed Infrastructure	Intact Infrastructure
BR939A	20	1.100	1.86	18.70
BR966 F2	9	0.730	1.26	18.80
BR966 F9	60	1.900	3.21	86.75
BI	9	0.531	0.90	14.72
CAA02	9	0.470	0.79	12.94
NT2A	9	0.469	0.79	12.91
D6	9	0.427	0.72	11.69
CAA04	9	0.290	0.47	7.70

Table 4 – Model 15a Single Track (CWR, Booster Sections, Return Conductor)
Calculated Permissible Interference Current

Relay Type	Relay Coil Resistance (Ω)	Drop Away Voltage (V)	Permissible Train Current Limit for Maximum Line Standard Track Circuit Length (A)	
			Failed Infrastructure	Intact Infrastructure
BR939A	20	1.100	1.71	5.40
BR966 F2	9	0.730	1.21	5.29
BR966 F9	60	1.900	2.81	21.68
BI	9	0.531	0.85	4.07
CAA02	9	0.470	0.75	3.58
NT2A	9	0.469	0.75	3.57
D6	9	0.427	0.68	3.23
CAA04	9	0.290	0.45	2.13

Table 5 – Model 17a Single Track (Jointed Rail, Rail Return and Earth-Wire)
Calculated Permissible Interference Current

Relay Type	Relay Coil Resistance (Ω)	Drop Away Voltage (V)	Permissible Train Current Limit for Maximum Line Standard Track Circuit Length (A)	
			Failed Infrastructure	Intact Infrastructure
BR939A	20	1.100	3.21	16.58
BR966 F2	9	0.730	2.23	16.82
BR966 F9	60	1.900	5.80	78.85
BI	9	0.531	1.60	13.21
CAA02	9	0.470	1.40	11.61
NT2A	9	0.469	1.40	11.58
D6	9	0.427	1.27	10.49
CAA04	9	0.290	0.84	6.91

Table 6 – Model 19a Single Track (CWR, Rail Return and Earth-Wire) Calculated Permissible Interference Current

5.3 Double Track Railway: Intact and Failed Infrastructure

For a double track railway the analysis presented in ref. [\[5025773-L-TR-002\]](#) & [\[LRDA40278/124/93003\]](#) is summarised in Tables 7, 8, 9 and 10 below.

The calculations carried out by each of the four models are detailed below:

- DCMOD14a: double track railway, jointed rail, booster sections with return conductor.
- DCMOD16a: double track railway, CWR, booster sections with return conductor.
- DCMOD18a: double track railway, jointed rail with rail return.
- DCMOD20a: double track railway, CWR with rail return.

Each of the four models has been used to calculate limits for both intact infrastructure and failed infrastructure.

Relay Type	Relay Coil Resistance (Ω)	Drop Away Voltage (V)	Permissible Train Current Limit for Maximum Line Standard Track Circuit Length (A)	
			Failed Infrastructure	Intact Infrastructure
BR939A	20	1.100	1.76	9.42
BR966 F2	9	0.730	1.18	8.32
BR966 F9	60	1.900	2.91	29.79
BI	9	0.531	0.84	6.24
CAA02	9	0.470	0.74	5.49
NT2A	9	0.469	0.74	5.48
D6	9	0.427	0.67	4.96
CAA04	9	0.290	0.44	3.27

Table 7 – Model I4a Double Track (Jointed Rail, Booster Sections, Return Conductor) Calculated Permissible Interference Current

Relay Type	Relay Coil Resistance (Ω)	Drop Away Voltage (V)	Permissible Train Current Limit for Maximum Line Standard Track Circuit Length (A)	
			Failed Infrastructure	Intact Infrastructure
BR939A	20	1.100	7.18	24.29
BR966 F2	9	0.730	5.17	23.89
BR966 F9	60	1.900	14.45	107.31
BI	9	0.531	3.77	18.71
CAA02	9	0.470	3.32	16.45
NT2A	9	0.469	3.31	16.41
D6	9	0.427	2.99	14.86
CAA04	9	0.290	1.97	9.78

Table 8 – Model I6a Double Track (CWR, Booster Sections, Return Conductor) Calculated Permissible Interference Current