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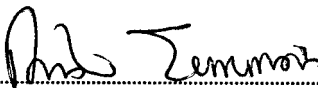
Ref	NR/SP/SIG/50006
Issue	1
Date	April 2006

Business Process Document

Methodology for the Demonstration of Compatibility with 50 Hz Double Rail Track Circuits

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Published & Issued by: Network Rail 40 Melton Street, London NW1 2EE



Ref:	NR/SP/SIG/50006
Issue:	I
Date:	April 2006

Issue record

Issue	Date	Comments
I	April 2006	Issue validated and endorsed by ESRP

Implementation

(Please include implementation date, if applicable.)

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I Purpose

The purpose of this document is to provide a methodology for the demonstration of electromagnetic compatibility (EMC) of rolling stock with 50 Hz double rail track circuits installed on Network Rail controlled infrastructure. It is based upon previously accepted safety assessments, which were undertaken for traction and rolling stock thereby allowing them to operate over 50 Hz double rail track circuits.

2 Scope

The methodology provided in this document applies to rolling stock manufacturers who are providing the EMC safety case with 50 Hz double rail track circuits as part of the acceptance process.

The methodology is split into two distinct parts – one that considers the effect of steady state electromagnetic interference (EMI), and the other which considers the effect of transient EMI. The methodology predicates the use of the fully validated model of the double rail 50 Hz track circuit possessed by Network Rail which can be provided to persons presenting such a safety case albeit an alternative approach is also presented.

3 Reference documentation

3.1 Network Rail Company Standards

RT/E/S/11752	"Train Detection", Issue 2, dated August 2001
RT/E/PS/11757	"A.C. Phase Sensitive Track Circuits", Issue 1, dated December 2000
RT/E/C/50005	"Methodology for the demonstration of compatibility with 50 Hz single rail track circuits", Issue 1, dated February 2003
RT/E/S/21136	"Track Circuit Operating Device", Issue 2, October 1999

3.2 Previous Safety Case Documentation

I20-dr0262	"50 Hz Double Rail Track Circuit Traction Current Interference
[AEAT Rail]	Susceptibility", version a0, 2 October 1997
I20-dr0361	"Class 365/5 Networker Express EE&CS EMC Safety Assessment for D.C.
[AEAT Rail]	Operation, 50 Hz Double Rail Track Circuit", version c0, dated 12th December 1997

3.3 Other standards

Track Circuit Manual	Former BR Southern Region S&T Dept, Issue 02 dated 6/91
BS EN 50238:2003	"Railway Applications: Compatibility between Rolling Stock and Train

Detection Systems”

[BS EN 50121-3-1:2000](#)
[UIC 737-3 R](#)

“Railway Applications – Electromagnetic Compatibility Part 3-1: Rolling stock – train and complete vehicle”
 “Application of thyristors in railway technology – Measures for the prevention of functional disturbance in signalling installations”, UIC leaflet 1st edition 1-7-1985

3.4 Other Documentation

[Power Magnetics and Electronic Systems Limited, Ref: 2115 ESID9165 \[AEAT Rail\] LRDA D9280 \[AEAT Rail\] BS IEC 61508](#)

"Final Report, Measurement of 50 Hz Harmonic Levels on 750V DC Traction Supply System for Railtrack PLC Contract No. 90218", Issue 1, March 1996
 “50 Hz Track Circuit Model - User Guide”, Issue 10, January 2002
 “Effect of Transmission Lines on 50 Hz Track Circuits”, Issue 1, November 2003
 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems

4 Description of 50 Hz Double Rail Track Circuit

Double rail 50 Hz track circuits are used extensively on d.c. electrified plain lines as they allow both rails to be used for traction current return. (Generally, single rail track circuits are only used in areas of points and crossings and for short sections.)

At the boundaries of the track circuit the rails are fitted with insulated rail joints (IRJ). These limit the 50 Hz track circuit operating current to that particular section, the dc traction return current flows into the next section via an impedance bond, which is connected across the IRJ, the arrangement is shown in Figure 1.

The principle of operation is that when no vehicle occupies the track circuit the feed current flows from the feed end to the track circuit relay via one rail and returns by means of the other. This current lifts the relay vane, which in turn closes the front contacts of the relay. If a train occupies the track the wheels and axles constitute a low impedance path which connects the two rails together, effectively short circuiting the relay; current ceases to flow through the relay and consequently the vane drops, opening the front contacts.

The 50 Hz operating current is injected into the rails by the transformer action between the auxiliary winding (t0, t1) and the traction winding (T0, T1) of the feed end impedance bond.

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At the relay end the 50 Hz track circuit operating current flows via the traction winding (T0, T1) of the impedance bond and hence induces a voltage across the auxiliary winding (t0, t1).

Typically the turns ratio between the auxiliary winding (t0-t1) and the traction winding (T0-T1) is 56:1. The feed end auxiliary winding is connected to the 110 V signalling supply via the feed transformer. By adjusting the feed and relay capacitors the overall circuit is tuned to resonate close to 50 Hz, although it is important that the relay circuit does not operate on the capacitive side of resonance as this can cause a low impedance path which acts as a sink for 50 Hz currents and can cause wrong side failure (WSF) without traction interference.

The relays used in 50 Hz double rail track circuits are double element vane relays, which contain two coils. One coil, called the local coil, is connected to the 50 Hz signalling power supply, whilst the second coil, denoted the control coil, is connected to the auxiliary winding of the relay end impedance bond [[RT/E/S/11752](#)]. If there is no train within the boundaries of the track circuit, the voltage across the control coil is phase displaced by approximately 90 degrees to that of the local coil voltage, this is a necessary condition as the relay vane will not pick up with an excessive or insufficient phase displacement.

The traction return current bypasses the insulated rail joints by means of the impedance bonds. The traction winding centre taps of adjacent impedance bonds are connected with each other. If the track circuit is perfectly balanced any current which enters at a train shunt (i.e. axle), at a centre-tap of a feed end impedance bond, or an intermediate impedance bond, will flow equally through both running rails and exit the track circuit at the centre-tap of the relay end bond. Since the currents in each traction half-winding of the relay end bond are equal and opposite, no net flux linkage of the auxiliary winding is produced and consequently, no component of the traction current is present in the relay control coil, even if it contains a 50 Hz signal. In practice there is likely to be some degree of imbalance, which will provide a mechanism to produce a small current flow through the relay, defined as the “interference current”. This current is dependent upon the balance of the track circuit as a whole.

Up to two intermediate bonds may be installed in a track circuit, which in total may be up to 2.5 km in length [[RT/E/PS/11757](#)]. Generally, single sections between intermediate impedance bonds within track circuits do not exceed 1100 m (max 825 m in [120-dr0361 \[AEAT Rail\]](#)) in length. Non-standard track circuits with three intermediate impedance bonds do exist. Intermediate impedance bonds are set up to be at resonance, this is achieved by means of an auxiliary capacitor, the resonance results in a high shunt impedance to 50 Hz being presented across the running rails. The presence of intermediate bonds affects the resonant characteristics of the track circuit, with the result that intermediate capacitors are often set off-resonance in order to give the desired overall response at the relay.

In addition to using both running rails the conductivity of the return path is increased by parallel connection of adjacent lines and/or reinforcing conductors. This is achieved by connecting the centre plates of impedance bonds (Figure 1) on parallel running lines with each other. Cross bonding has the overall effect of reducing traction current flowing

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through any particular line since a proportion of the traction current flows through adjacent lines.

Currently there are four different types (0 - 3) of impedance bond and of each type there are a number of models from different manufacturers. The latest impedance bond is the type 3, which is also the standard replacement. All bond parameters required for this EMI assessment are listed in Appendix A. It has been previously demonstrated that an assessment of a track circuit using type 3 bonds encompasses the other types of bond that may be encountered [[I20-dr0262 \[AEAT Rail\]](#)].

There are three types of relay in common use: VTI, CE39I and G4. The VTI relay is predominant, and is the standard replacement [[RT/E/PS/I1757](#)]. Each relay type has different control coil impedance; these are presented in Appendix A. The control coil impedance is frequency dependent and the value shown in Appendix A refers to a frequency of 50 Hz. The pick up voltage for the three relay types with varying frequency is given here in figure 2. The relay will only stay continuously 'picked' if the frequency of the signal applied to the local coil is the same as that applied to the control coil. If the frequencies applied are different the relay will alternately pick and drop.

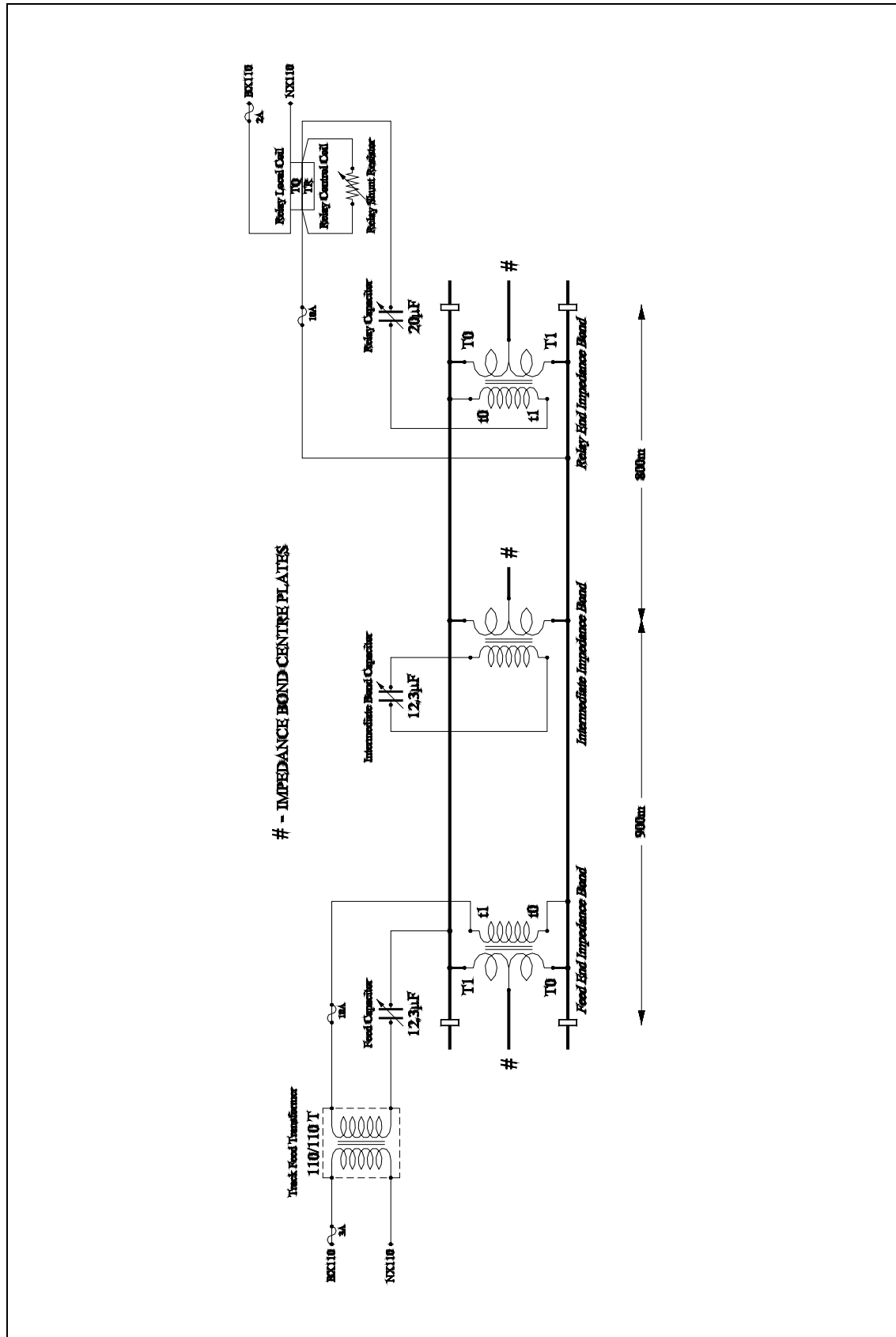


Figure I: Typical 50 Hz double rail track circuit.

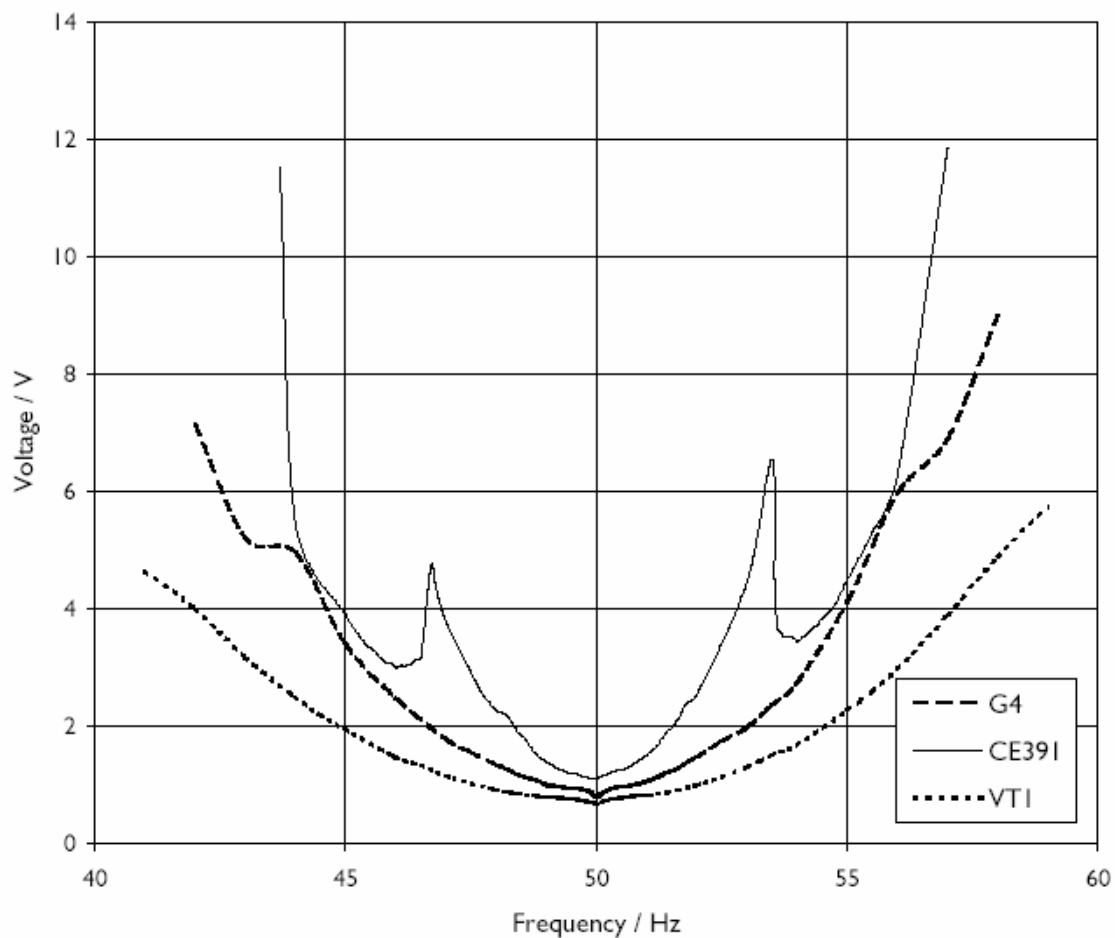


Figure 2: 50Hz Relay responses (pick up voltage) for a control coil frequency of 50 Hz

N.B. This figure should not be taken to imply that the relay can be adequately represented by a filter characteristic.

5 Infrastructure Assumptions and Terminology

- Double rail 50 Hz track circuits are correctly installed and maintained in accordance with [RT/E/PS/11757](#).
- Double rail 50 Hz track circuits can be considered to fall into one of three categories:

Normal

Track circuits which contain an intact, correctly phased, relay circuit which is set up at resonance or on the inductive side of resonance. Also these track circuits contain no electrical discontinuities, e.g. broken rails or broken side leads.

Out of limits

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Track circuits which are set up incorrectly, e.g. with excess capacitance or incorrectly phased impedance bond auxiliary coil.

Completely unbalanced

Track circuits in which the relay end impedance bond is completely unbalanced due to either a broken side lead (i.e. an electrical discontinuity in the traction path between a running rail and the relay end impedance bond centre-plate) or a broken rail (i.e. an electrical discontinuity in a running rail).

- The analysis presented in [120-dr0262 \[AEAT Rail\]](#) has found that track circuits that are out of limits or completely unbalanced are extremely susceptible to 50 Hz interference current, see section 5.1.6. Therefore it is necessary for new rolling stock to demonstrate that average levels of 50Hz emissions of the new train over the length of the route of interest are not worse than existing rolling stock on the route.
- A budget is applied to the susceptibility of track circuits so that 1/3 of the total interference required to operate the relay is assumed to flow from other trains in the section, 1/3 is assumed as a safety margin including an allowance for background interference, leaving 1/3 as the limit of interference which can be safely generated by a train. This assumes that all interference flowing from trains and all background interference is in phase. The use of this budget means that the calculated susceptibility levels are very pessimistic and are applicable to all normal configurations of 50 Hz double rail track circuits. This budget is in accordance with [UIC 737-3 R](#).
- It is pessimistically assumed that the conductor rail is adjacent to the same running rail for the entire length of a track circuit.
- A low ballast conductance of 0.1 Skm-1 is assumed.
- Normally the length of feeder sections between substations is about 6 km. However, to establish a more pessimistic scenario, a distance of 7.5 km is assumed.
- The balancing effects of intermediate bonds are not included in the analysis.
- The term 'new train' refers in this document to the train subject to this EMI analysis and to be introduced on sections of track with 50 Hz track circuits.
- The term 'existing train' refers in this document to a train currently operating on the route under consideration for which the new trains are destined.
- It is assumed, that existing trains used on the route operate with an acceptable level of safety on 50 Hz double rail track circuits [\[RT/E/C/50005\]](#).

Note: these infrastructure assumptions are used in [120-dr0262 \[AEAT Rail\]](#) and provide the basis of the analysis presented in section 6.

6 Susceptibility Analysis

Due to the dynamic characteristic of the track circuit relay, the effects of steady state EMI are quite different than those from transient EMI; where steady state and transient can be defined as: