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Methodology for the demonstration of compatibility with 50 Hertz single Rail track circuits. (formerly RT/E/C/50005)

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METHODOLOGY FOR THE DEMONSTRATION OF COMPATIBILITY WITH 50 HERTZ SINGLE RAIL TRACK CIRCUITS

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IMPLEMENTATION

The provisions of this code of practice may be used from the date of issue.

COMPLIANCE

(Please include compliance date and if it is mandatory upon Railtrack/Contractors/Lessee)

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1. Introduction

The purpose of this document is to provide a methodology for the demonstration of electromagnetic compatibility (EMC) of rolling stock with 50 Hz single rail track circuits installed on Railtrack 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 single rail track circuits.

The methodology is split into two distinct parts – one which considers the effect of steady state electromagnetic interference (EMI), and the other which considers the effect of transient EMI on the 50 Hz single rail track circuits.

2. Source Documents

2.1 Group Standards

- 1 Former BR Southern Region S&T Dept, Track Circuit Manual – Issue 02 dated 6/91

2.2 Line Standards

- 2 RT/E/PS/11757 Railtrack Line Product Specification "A.C. Phase Sensitive Track Circuits", Issue 1, dated December 2000
- 3 RT/E/S/11752 Railtrack Line Specification "Train Detection", Issue 1, dated December 2000

2.3 Previous Safety Case Documentation

- 4 "Class 365/5 Networker Express EE&CS EMC Safety Assessment for D.C. Operation, 50 Hz Single Rail Track Circuit Results of Traction Interference Modelling", AEA Technology Rail, 120-dr293, version a2, dated 11th December 1997.
- 5 "50 Hz Single Rail Track Circuit Model Validation", AEA Technology Rail, 120-dr0292, version a1, 7 December 1997.
- 6 "50 Hz Double Rail Track Circuit Traction Current Interference Susceptibility", AEA Technology Rail, 120-dr0262, version a0, 2 October 1997.

- 7 "Class 365/5 Networker Express EE&CS EMC Safety Assessment for D.C. Operation, 50 Hz Single Rail Track Circuit", AEA Technology Rail, I20-dr276, version b0, dated 18th December 1997.

2.4 Other Documentation

- 8 British Standard Institution: "BS EN 50121-3-1: 2000, Annex A: Calculation of the overall psophometric current of a train-set", Railway Applications – Electromagnetic Compatibility Part 3-1: Rolling Stock – Train and Complete Vehicle, December 2000.
- 9 "Final Report, Measurement of 50 Hz Harmonic Levels on 750V DC Traction Supply System for Railtrack PLC Contract No. 90218", Power Magnetics and Electronic Systems Limited, Log Ref: 2115, Issue 1, March 1996.
- 10 "Railway Safety - HM Chief Inspecting Officer of Railways' Annual Report on the safety record of the railways in Great Britain during 1995/6" HSE Books
11 "50 Hz Track Circuit Model - User Guide", AEA Technology Rail, ESID9165, Issue 10, January 2002

3. Description Of 50 HZ Single Rail Track Circuit

The normal arrangement on d.c. electrified lines is for both running rails to be used for the traction return current to provide the lowest possible resistance. This is the case on plain line and track circuits are therefore normally provided in a double rail configuration. However points and crossings and locations where the track length is short necessitate the use of single rail track circuits [1, 2].

Fig. 1 shows a typical single rail track circuit with the feed on the left-hand side of the diagram and the relay on the right. The signal rail is fitted with insulated rail joints (IRJs) at the track circuit boundary. The traction return rail is continuous and is not insulated from adjacent track circuits.

The principle of operation is when there is no vehicle within the track circuit's boundaries the current flows from the feed 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, i.e. opening the front contacts.

The transformer is used to isolate the track circuit from the signalling supply. The circuit current is adjusted by means of the adjustable feed capacitor. The stabilising rectifier connected to the control coil of the relay is intended to limit the effect of interference. This device is a selenium rectifier which presents a low impedance at high voltages, such devices can fail and an open circuit failure is not revealed. Hence to ensure that the analysis is pessimistic it is prudent to assume that this device has failed i.e. open circuit. [4].

The relays used in 50 Hz track circuits are double element vane relays, which contain two coils. One coil, called the local coil, is connected to the 50 Hz signalling supply, whilst the second coil, denoted the control coil, is connected to the signal rail and traction return rail [5].

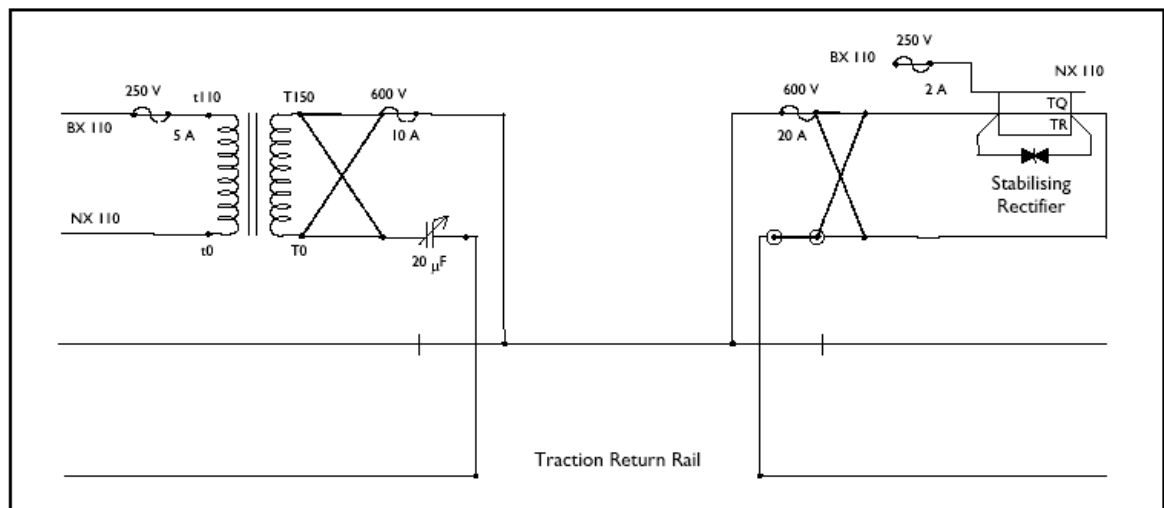


Figure 1: 50 Hz single rail track circuit configuration.

The maximum length of single rail track circuits is normally 200 m, but may increase to 300 m in terminal platforms. As a general principle track circuits are arranged so that trains normally enter at the feed end and exit at the relay end [1].

There are three types of relay in common use: VTI (and the VTI(SP) variant), CE39I and G4 of which the VTI relay is the most common [6]. Each of the relay types has its own characteristic with different control coil impedance, pick up voltage and drop away voltage (table I). The control coil impedance is frequency dependent and the value shown in table I refers to the nominal value at a frequency of 50 Hz [6].

Relay type	50 Hz impedance / Ω	Pick-up voltage / V	Drop away voltage / V
VTI	$3.5 + j\ 0.2$	0.50	0.45
CE39I	$5.2 + j\ 2.5$	1.16	0.74
G4	$1.7 + j\ 4.0$	0.60	0.57

Table 1: Relay Parameters.

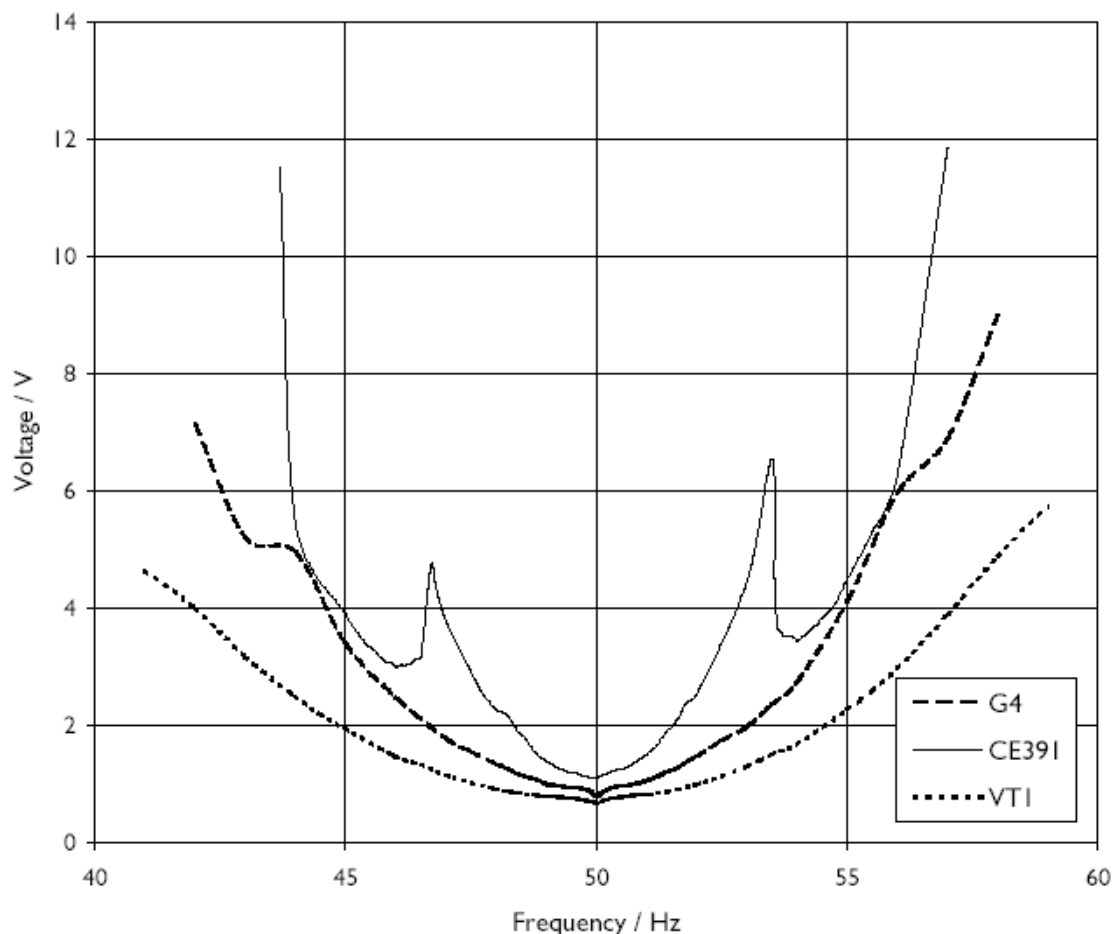


Figure 2: 50Hz Relay responses (pick up voltage) for a control coil frequency of 50 Hz

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

Typical responses for the three common relay types are shown in figure 2. This figure shows the voltage required to 'pick up' the relay for frequencies around 50 Hz. The lowest point of the response curve corresponds to the frequency of the control coil and is therefore dependent on the frequency supplied to this coil. The only situation that will result in the relay being picked indefinitely is when the control and local coils

are supplied with the same frequency and the phase relationship is correct. Any other frequency will result in an oscillating torque (at the beat frequency) being induced in the vane and the relay will alternately pick and drop. Therefore a filter representation of the response shown in figure 2 is not appropriate for the modelling of 50 Hz track circuits.

4. Infrastructure Assumptions And Terminology

The methodology presented utilises the following assumptions:

- 50 Hz single rail track circuits are correctly installed and maintained in accordance with the Track Circuit Manual and/or the relevant Railtrack Company Product Specification [1, 2]. Whilst the Track Circuit Manual is a superseded document it is considered an adequate reference source for 50 Hz track circuits as it was the installation standard in use when the majority of them were installed.
- The length for assessment of the 50 Hz single rail track circuit is assumed to be 200 m.
- Track circuits with a length greater than 200 m are assumed to have cross bonding which means that not all the traction return current from a train will flow the full length of the track circuit. Track circuits longer than 300 m are generally installed in terminal platforms where there is likely to be more cross bonding and fewer trains will be able to draw traction current over the track circuit in question.
- No 'slow to pick' track repeat relays (TPR) are fitted. It is known that not all track circuits are fitted with TPR's and of those that are, it cannot be assumed that only the TPR contacts are used for signalling/control functions.
- To consider a normal (unfailed) pessimistic track circuit, all traction current is assumed to flow via the traction rail in one direction.
- Absence of the Westalite stabilising rectifier
- The term 'new train' refers in this document to a train subject to EMI analysis and to be introduced on routes with 50 Hz single rail track circuits.
- The term 'existing train' refers in this document to a train currently operating on the route of interest. It is assumed that existing trains operate with an acceptable level of safety on 50 Hz single rail track circuits fitted on the route [1], [7].
- The track is assumed to be of standard gauge
- The sleepers in use are assumed to be concrete or wood, steel sleepers are not included in the analysis presented here.
- UIC 60 Rail is not included in the assessment as presented. The methodology given here is applicable but the parameters of this rail type at the frequency of interest will need to be determined and used in the appropriate calculation.

- The presence of check rails will reduce the effective impedance of the rail to which they are attached. This is not included in this document, however the methodology provided allows for the effect of such differences to be evaluated.

5. Susceptibility Analysis

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

- **Steady state** A particular level of current which exists for a time greater than the general range of relay operating times. Typically this is a time greater than 0.5 seconds. For steady state analysis only the amplitude of the current is of interest.
- **Transient** Short duration and/or changing levels of current when compared to the dynamic response of the relay vane, typical events being step changes in traction current. The response of the relay will lag that of the electrical initiating event and may occur after the electrical event has ceased. For this analysis the mechanical dynamic performance of the relay must be included in the analysis.

5.1 Substation Voltage Ripple

It is known that the d.c. traction power supply contains a 50Hz component due to its derivation from the mains supply. Due to this voltage ripple on the supply any train will conduct a 50 Hz current dependent on the impedance that the train presents to the supply at 50 Hz. Therefore the 50 Hz current due to a train present on a particular track circuit is made up of two components, that due to conduction of 50 Hz current from the supply and that generated by the train itself.

Measurements have indicated that the 50Hz harmonic ripple on the d.c. traction supply is of the order of 0.1 V to 2 V [9]. However the level of 50 Hz ripple to be used in any particular safety assessment should be declared to Railtrack at the start of the project.

5.2 Steady state analysis

Since the electrical supply to the local coil of the relay is ultimately derived from the mains then the frequencies of interest generated or conducted by the train are those between 48 Hz and 52 Hz thereby allowing for the effect of mains frequency variation

on the local coil. The track circuit being a vane relay, which is an electromechanical device, has a dynamic response characteristic. This precludes it being modelled simply as a filter; differences between the frequencies of the currents flowing in the local and control coils can result in a beating torque being set up in the vane. Generally these are shorter than the response time of the vane and it does not react to them. The vane relay will only respond to low frequency torque oscillations.

5.2.1 Interference Mechanism

The configuration of the interference mechanism for single rail 50 Hz track circuits is shown in fig. 3. The equivalent circuit of the interference mechanism is shown in fig. 3. The axle indicates the location of the train.

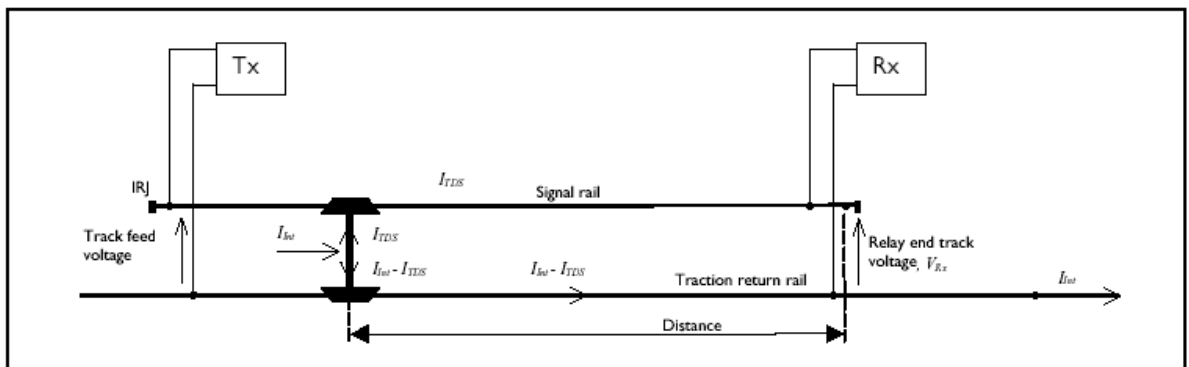


Figure 3: 50 Hz track circuit configuration.

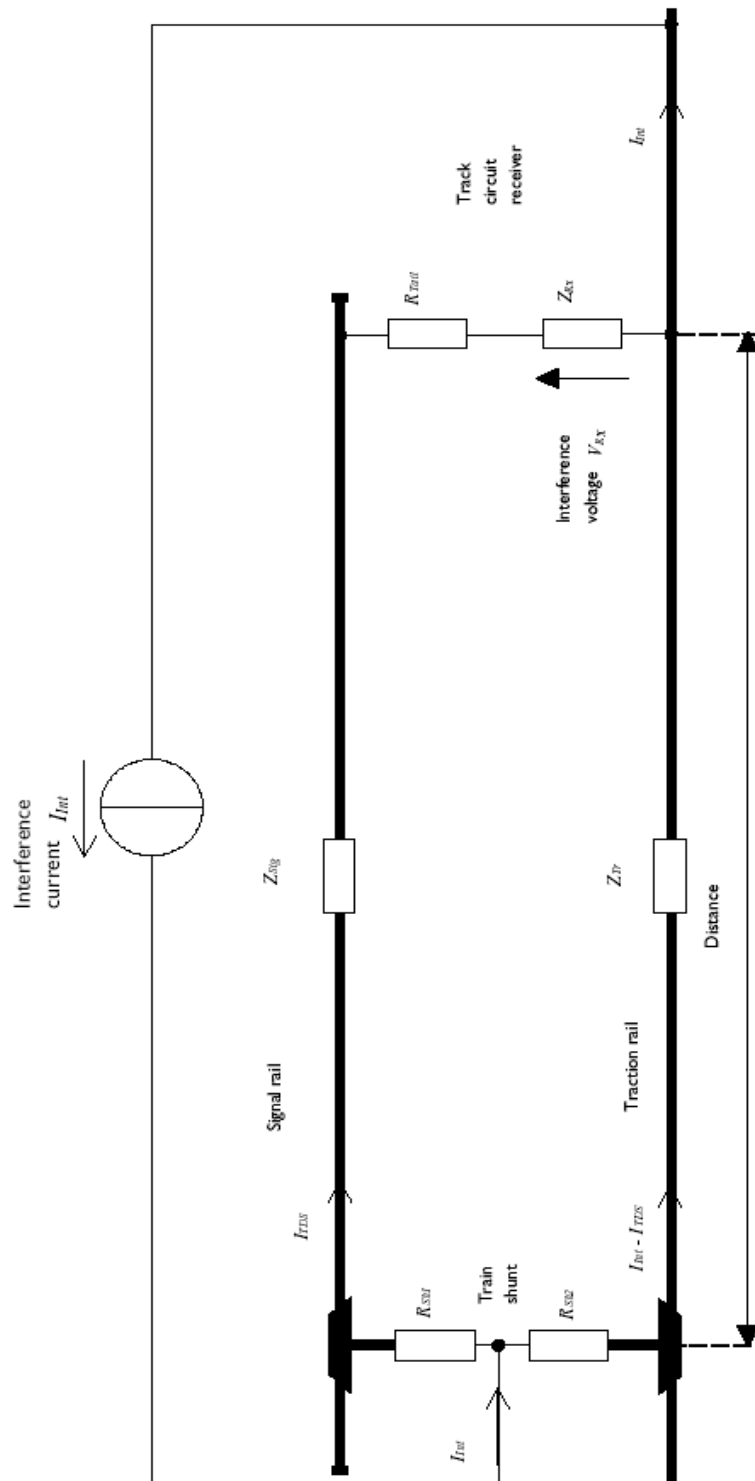


Figure 4: Wrong side failure mechanism.