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Methodology for the demonstration of compatibility with TI 2I Track Circuits (formerly RT/E/C/50008)

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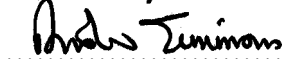
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METHODOLOGY FOR THE DEMONSTRATION OF COMPATIBILITY WITH TI 21 TRACK CIRCUITS

ENDORSEMENT & AUTHORISATION

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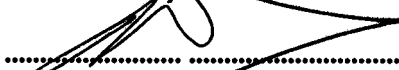
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I	February 2003	New Code of Practice

IMPLEMENTATION

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

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1. INTRODUCTION

1.1 Purpose

The purpose of this procedure is to provide a method for calculating the safe permissible maximum levels of electrical interference that may be generated by electric trains designed to be used on tracks employing TI 2I track circuits. The procedure lists all of the infrastructure aspects to be taken into account, characteristics of the TI 2I track circuits and possible failure modes. Worked examples are given for calculating maximum permissible levels of electrical interference due to traction current, and axle-to-axle voltages.

1.2 Scope

The scope of this procedure is that of providing a method for presenting calculations in support of a safety case for the operation of electric trains over TI 2I track circuits. All components relevant to TI 2I track circuits are considered.

The document only considers double rail configuration with balanced earth connections.

The electrification installed is assumed to be of the standard arrangement, auto-transformer fed sections of railway are not included.

Traction bonding is assumed to be compliant with the requirements of RT/E/PS/11761 [2].

1.3 Installation types covered in this document

This procedure may be used for the operation of trains over Railtrack 25 kV a.c. or 750 V d.c. electrified routes. The levels derived define the maximum permitted interference generated by a single train. Double rail end-fed and centre fed TI 2I track circuits are considered.

On a.c. electrified routes the catenary support and other lineside metal structures are bonded to traction return rails. This document relates to double rail installations only and these are nominally balanced. The TI 2I track circuit requires both rails to be balanced with respect to voltage to earth and current flow in each rail. Therefore, in TI 2I areas the catenary support structures are often bonded to a dedicated earth wire connected to the rail via impedance bonds [1].

On d.c. electrified routes neither of the rails is intentionally bonded to earth, hence balance is maintained. In a completely balanced situation, the TI 2I track circuit is in theory immune to any amount of traction current or interference produced by a train.

1.4 Equipment types included in this document

The equipment types included in this document are the type designated TI2I-I used in the UK. These are assumed to be installed only in double rail mode in jointless configuration.

2 SOURCE DOCUMENTS

2.1 Relevant Railway Standards

1. 'Track Circuit Requirements for AC Traction - Code of Practice', Safety & Standards Directorate, Railtrack, Fitzroy House, 355 Euston Road, London NW1 3AG, Reference GK/RC 0753, Issue 1, June 1996.
2. 'Railtrack line Product Specification TI.2I Audio Frequency Track Circuits.', Railtrack, Reference RT/E/PS/I 1761, Issue 1, December 2000.
3. 'Electrified Lines Traction Bonding', Safety & Standards Directorate, Railtrack, Fitzroy House, 355 Euston Road, London NW1 3AG, Reference GL/RT 1254, Issue 1, April 2000

2.2 Previous Safety case documentation

4. 'GEC Alsthom Juniper Project TI2I Track Circuit Interference Limits AC and DC Routes' AEA Technology Rail, Issue 2, 7 January 1999, Report reference PRJ-SCSE(JUN)-RP-7
5. 'Track parameters for Interference studies' N Rambukwella, AEAT Rail Report number STG-D-EPS(373)RP-18, Issue 1, January 1995.
6. 'Class 92 Locomotive EMC Safety Assessment – Volume 5 TI2I Track Circuits, Fleet Operation on the Route between Crewe and Doncaster', AEA Technology ref. I20-dr0459, version b0, dated February 1999.

7. "TI2I Track Circuit Proof of Safety", ABB Signal Ltd, dated 11th October 1993.

3. INFRASTRUCTURE ASSUMPTIONS

The main assumptions that may be made while carrying out an analysis are summarized below.

- For a track circuit with a TTU (Track Tuning Unit), the analyses are carried out for each of the TI 2I frequencies, abutting the other frequency of the allowable pairing at a tuning unit.
- For a track circuit with an ETU (End Termination Unit), the analyses are carried out for each of the TI 2I frequencies.
- A rail resistance of $1 \Omega/\text{km}$ and rail inductance of $675 \mu\text{H}/\text{km}$ is used over the TI 2I frequency band. This is in accordance with measured parameters for BS113a rail with an allowance for jointed track [4, 5].
- 100% imbalance is assumed, this is pessimistic compared to the nominal imbalance values of 60%/40% in the case of 25 kV a.c. power supplies and 70%/30% in the case of 750 V d.c. power supplies. [4]
- Other track circuits may be assumed to be balanced. Interference current from trains on other track circuits will therefore be significantly less than that on the track being analysed, and will be covered by an interference allowance.
- The impedance of the cables used for cross bonding is ignored.
- The reduction of rail current due to earth return currents (either intentional or due to leakage) can be ignored. This means that all return current is in the rails. Worst-case interference propagation is therefore considered.
- The effect of multiple interfering sources may be ignored since these are covered by interference allowances.
- All track circuit components are assumed to be installed to Railway Group standards and components are at their nominal values.
- Bond types ABB B3/500 and Westinghouse Style S are analysed for a.c. and d.c. traction systems respectively. These are considered to be representative.
- The maximum length considered is that stated in ref. 2 that is 1 km.

- The receiver is assumed to be set at its most sensitive setting (there are 13 settings in total).
- 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.
- Track boosting capacitances are excluded from the scope of this assessment.
- Traction bonding is assumed to be compliant with the requirements of RT/E/PS/11761 [2].

The following assumptions are made in the assessment of axle-to-axle voltages:

- The train producing axle-to-axle voltage does so at a spacing equal to the cross-bond spacing. Current flow in the train and track under the train are not considered. [4]
- Minimum cross-bond spacing is 100 m. [4]
- The train producing interference is in a track adjacent to that on which the track circuit in question is installed. This being the only parallel track.

3.1 Imbalance

The double rail TI 21 track circuit is intended to operate as a balanced system. For all current 25 kV schemes using this type of track circuit, the balance is maintained by avoiding any connections to the rails that could unbalance the track circuit. This is achieved by using an earth wire for structure bond connections. Earthing and traction return connections to the running rails are via impedance bonds. However, due to the different mutual inductances between each of the traction return rails and the earth wire, an imbalance of traction return current (and hence train interference current) will occur. The probable value of this imbalance is noted in the assumptions above. It is further assumed that the imbalance component of the noise current will flow in the TI 21 track circuits.

In third rail d.c. electrified areas, none of the rails are earthed and the traction return connections are made via TI 21 impedance bonds. When the track circuit is fully balanced, any traction return current will be presented equally to each input terminal of the track circuit receiver, and will have no effect on its operation. A wrong side

track circuit failure due to interference can only occur when there is some imbalance present.

Imbalance at track circuit frequencies can be caused by:

- 1 Unequal earthing of each rail through the ballast
- 2 Presence of check rails or similar
- 3 Differences in electrical characteristics of rails, bonding differences between each rail or series bonding
- 4 Earthing of either rail
- 5 Asymmetrical position of the conductor rail or catenary relative to the running rails
- 6 Track curvature

A broken rail (i.e. an electrical gap in continuity) will probably cause a right side failure of the track circuit. This will therefore be detected in a short time. The other causes of imbalance will be less significant, but the actual amount of imbalance is difficult to predict.

The presence of cross bonding has no direct effect on the track circuit, since all cross bonds are connected via impedance bonds. Whilst the impedance between the cross-bond center tap on the impedance bond and either rail, being low at traction current frequencies (d.c. or 50 Hz), it is somewhat higher at TI 2I frequencies. If a short circuit develops within the impedance bond, which connects the cross bond directly to one rail, the resonant frequency of the impedance bond will be reduced. The impedance at TI 2I frequencies will reduce significantly, and the track circuit will be shunted. This will cause a right side failure and it will be detected.

At points and crossings the ends of a TI 2I section will be connected to other types of track circuits via impedance bonds, therefore any failure of these bonds will also cause a right side failure. In a balanced system, there is little possibility of interference currents circulating via the cross bonding. This is because of the relatively high impedance of the impedance bonds at TI 2I frequencies. Since an impedance bond failure will be detected, multiple failures are considered incredible and are therefore not analysed. Rail impedance at TI 2I frequencies is relatively high, and any unbalanced interference generated by trains outside the track circuit being analysed will be attenuated by the rail impedance and shunted by the tuning units.

Thus, only one failure mode needs to be analysed: a train occupying a track circuit with 100% imbalance.

At TI 2I frequencies (nominally 2 kHz), a rail resistance of $1 \Omega/\text{km}$ and a total rail inductance of $675 \mu\text{H}/\text{km}$ are used in the calculations. A rail resistance of $0.72 \Omega/\text{km}$

and a rail inductance of $677 \mu\text{H/km}$ [4], have also been obtained from a series of tests over a range of frequencies.

The $1 \Omega/\text{km}$ rail resistance is considered in this procedure to be a pessimistic assumption to take into account the effect of rail bonds in a jointed track.

The effects of ballast resistance are negligible, as it is assumed to be infinite, although the effects of ballast capacitance are considered in the analysis. An infinite ballast resistance is the worst case for interference propagation in this analysis. The presence of ballast resistance will shunt the interference current and could reduce the amount of interference reaching the receiver [4].

4. DESCRIPTION OF TRACK CIRCUIT

The TI 21 is a jointless track circuit operating in the audio frequency band, in the range 1532 Hz to 2610 Hz. TI 21 track circuit equipment fitted to Railtrack controlled infrastructure is given the designation TI 21-I to differentiate it from TI 21 equipment that is used in other countries. The primary differences between the different types are operating frequencies and modulation rates. The equipment considered comprises the following:

- TI 21-I Transmitter
- TI 21-I Receiver & relay
- Track tuning unit
- Impedance bond
- End termination unit

4.1 Track Circuit Frequency Range and Bandwidth

Each track circuit uses two frequencies separated by 34 Hz, as shown below in Table I. These are chosen to provide isolation between adjacent track circuits.

The bandwidth is:

- -3 dB at ± 6 Hz from each centre frequency
- -20 dB at ± 30 Hz from each centre frequency

Track Circuit Frequency Code	Nominal Frequency, Hz	Operating Frequency, Hz	
		Lower Frequency	Upper Frequency
A	1699	1682	1716
B	2296	2279	2313
C	1996	1979	2013
D	2593	2576	2610
E	1549	1532	1566
F	2146	2129	2163
G	1848	1831	1865
H	2445	2428	2462

Table 1: TI 21 Track circuit operating frequencies

4.1.1 Frequency Allocation

Two nominal frequencies are used to signal each track, these are alternated to provide isolation. The permissible frequency combinations and allocations are shown in table 2, reproduced from [2].

Track Circuit Frequency Code	Use	
A	Down line	Frequencies for use in two track areas
B	Down line	
C	Up line	
D	Up line	
E	Down line	Additional frequencies for use in four track areas
F	Down line	
G	Up line	
H	Up line	

Table 2: TI 21 Track circuit channel allocations

4.2 Track circuit components

4.2.1 TI 2I Transmitter

Although the transmitter (Tx) is not considered in the interference assessment, details are included here for clarity in describing operation. A block diagram of the TI 2I transmitter is shown in Figure 1.

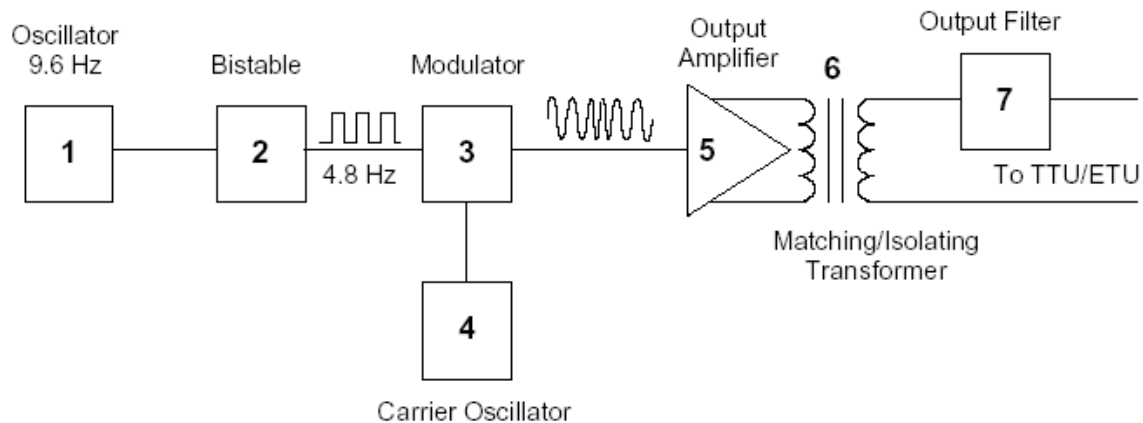


Figure 1: Block diagram of the TI 2I transmitter

The bistable (2) converts the output of the relaxation oscillator (1) from 9.6 Hz into a 4.8 Hz square wave. This frequency is used by the modulator (3) to modulate the output of the oscillator (4). The oscillator produces a signal that alternates ± 17 Hz either side of a carrier frequency at a rate of 4.8 Hz. The amplifier (5) increases this signal to a power level suitable for transmission to the track. A transformer (6) matches the amplifier output to the load. The filter (7) isolates the unit from unwanted d.c. and a.c. voltages. The signal is fed via a two-core cable to the associated Track Tuning Unit or End Termination Unit (TTU/ETU).

4.2.2 TI 2I Receiver and Relay

The track frequency is fed via a TTU or ETU to the receiver (Rx) which drives an a.c. immune, d.c. neutral, 50 V line relay acting as a Track Relay (TR). A block diagram of the TI 2I receiver is shown in Figure 2.

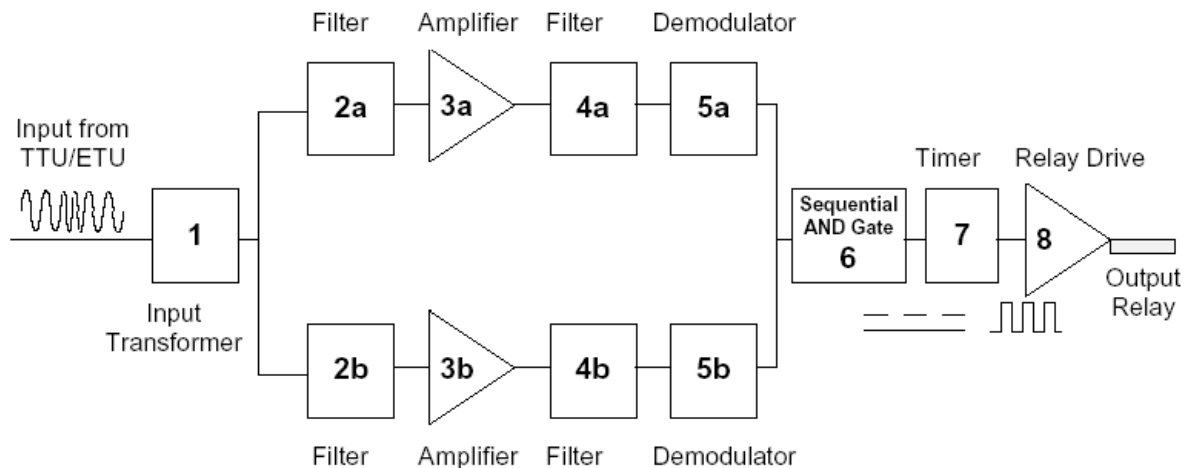


Figure 2: Block diagram of the TI 21 receiver

The input signal is fed from the TTU/ETU to the input transformer (1), which matches the receiver to the TTU/ETU and provides means of setting the overall receiver gain. The receiver has two parallel channels; one tuned to the higher frequency and one to the lower frequency. In each channel, the signal is filtered (2), amplified (3), filtered (4) and finally demodulated (5) so that a pair of anti-phase square waves are applied to the sequential AND gate (6).

The sequential AND gate only gives the required constant negative output when both the square waves are present in anti-phase to each other. This negative output is fed to a capacitor timer (7) which after a delay applies a nominal 50 V d.c. drive to an external output relay (8).

Immunity from interference is achieved because the presence of both frequencies correctly modulated is necessary for at least 2 seconds before the relay is energised [2]. Absence of the receiver input, due to a train shunt or any other reason, for a short period will disable the relay drive output.

The receiver will respond to signals outside the specified modulation range of the transmitter. In the early stages of TI 21 development the receiver was required to respond to a variety of modulation rates as part of a cab signalling/ATP system and the receiver design reflects this. The receiver will respond to modulation rates between 1.7 and 36 Hz [4]. The receiver can operate with an input signal duty cycle of up to 1:18, however this cannot be sustained at extremes of modulation rate [4].