

Category 1 Standard

S1193 Electromagnetic Compatibility (EMC) with LU Signalling System Assets

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1 Purpose

- 1.1 The purpose of this standard is to define the requirements for the management and control of sources of Electromagnetic Interference (EMI) so that any resulting disturbance to London Underground (LU) Signalling System assets is kept within acceptable limits.

2 Scope

- 2.1 This standard applies to any new or altered infrastructure, which is to be introduced or modified by any Supplier or Third Party, and for which it is credible that EMI generated or transmitted by the new or altered infrastructure will impact any LU Signalling System assets.
- 2.2 If any part of the new or altered infrastructure is located in the Vicinity of a LU route then the requirements of this standard apply to all elements that can credibly pose a threat to LU Signalling System assets.

3 Requirements

3.1 Safety plan

3.1.1 Contents

A safety plan shall be produced, documenting how the requirements of this standard will be met.

Note: The safety plan should describe:-

- a) The aims, extent and context of the change to be made, in terms of new or altered infrastructure;
- b) The engineering safety management techniques to be adopted to determine the risk presented by the new or altered infrastructure and to establish the safety requirements. This should include the validation of external items which will be incorporated in the new or altered infrastructure;
- c) The staff proposed for key safety roles (including Hazard identification and analysis) with justification for the competencies of the staff proposed;
- d) The competence and independence requirements for safety auditors and assessors; including the identity if known and applicable;
- e) The safety documentation which should be produced together with the staff responsible and the associated timescales;
- f) The engineering techniques, the use of which is planned in order to minimise the risk presented by the new or altered infrastructure (e.g. redundancy).

3.1.2 Acceptance

The safety plan shall be submitted to LU in accordance with standard S1538 clause 3.3.3 (h).

Note: The use of a Network Rail (NR) accredited Independent Safety Assessor (ISA) for validating Third Party Safety Case submissions will significantly help facilitate LU acceptance.

3.2 Identification of Hazards

3.2.1 Infrastructure identification and location

- 3.2.1.1 If any part of the new or altered infrastructure is located in the Vicinity of a LU route then the requirements of this standard apply to all elements that can credibly pose a threat to LU Signalling System assets.
- 3.2.1.2 The new or altered infrastructure shall be identified explicitly and its nature defined.
- 3.2.1.3 The geographical location of the new or altered infrastructure shall be identified unambiguously.

3.2.2 Asset identification

- 3.2.2.1 All affected LU Signalling System assets shall be identified and included in the corresponding assessments.
- 3.2.2.2 Information used in the identification of signalling equipment shall be obtained from a recognised source and shall be verified by a competent person as being accurate.

3.2.3 Hazard identification

- 3.2.3.1 All EMI coupling mechanisms and all resulting Hazards arising out of the operation of the new or altered source of EMI shall be identified.
- 3.2.3.2 The process of Hazard identification shall be carried out by persons with appropriate expertise in the Systems concerned, and a suitably rigorous methodology followed, to maximise the completeness of the Hazard log.
- 3.2.3.3 The Hazard identification process shall consider all phases of the new or altered infrastructure lifecycle.
- 3.2.3.4 Hazard identification shall continue throughout the new or altered infrastructure design, testing, commissioning and operational stages.

3.2.4 Third Party infrastructure

- 3.2.4.1 Third Parties shall identify and inform LU of any new or modified infrastructure that is considered to be a potential threat to LU Signalling System assets, using the process in Appendix 2.
- 3.2.4.2 LU shall notify suppliers about any Third Party new or modified infrastructure, as described in 3.2.4.1, of which they are aware.
- 3.2.4.3 LU and suppliers shall make their best endeavours to secure the co-operation of any Third Party organisations in complying with the requirements of this standard to ensure compatibility between the two infrastructures is maintained throughout any change.
- 3.2.4.4 In the event that any Third Party organisations are unable or unwilling to comply with all the requirements of this standard, suppliers shall;
 - a) Inform LU and seek direction on how to proceed;
 - b) Support LU in meeting the requirements of this standard.

3.3 System assessment

3.3.1 Risk assessment

3.3.1.1 An appropriate risk assessment shall be performed for each identified Hazard in accordance with the requirements of this standard and the results documented in the Safety Case.

3.3.1.2 The risk assessment process shall include the following stages:

- a) The EMI threat, caused by the new or altered infrastructure, shall be determined for all normal and credible failure conditions.
- b) This EMI threat shall be compared with the appropriate Signalling System immunity for all normal and credible failure conditions.

Note: This immunity shall be derived from the relevant Signalling System asset Wrong Side Failure (WSF) or Right Side Failure (RSF) immunity characteristics, appropriate interference budgets, transfer functions and the number of multiple interference sources.

- c) Where necessary (i.e. where the assessment shows that it is credible for interference generated by the new or altered infrastructure to be incompatible with the Signalling System immunity), appropriate mitigating measures shall be identified and the risk re-evaluated.

3.3.2 Risk acceptance criteria

3.3.2.1 Following the risk assessment process, the overall residual risk posed by the EMI shall be shown to be either 'Broadly Acceptable' or both 'Tolerable' and 'As Low As Reasonably Practicable' (ALARP). To this end, each Hazard shall be shown to comply with one of the following criteria.

- a) The Hazard cannot credibly cause the appropriate interference budget applicable to the new or altered infrastructure to be exceeded;
- b) The generic failure rate limits for a WSF or RSF caused by EMI, as defined in accordance with paragraph 3.3.3., are satisfied.

Notes:

Refer to LU standards S1521, Safety Decision Making & 1-526 (S1526), The Assessment and Management of Health, Safety and Environmental Risk.

Further guidance can also be found in the following documents

- 1- The principles of the safe management of engineering change: Guidance; &
- 2- The International Handbook for Engineering Safety Management, Volume 1, Principles and Process.

3.3.3 Generic failure rates

3.3.3.1 Generic WSF and RSF failure rates of Signalling System assets, as a result of EMI, shall be taken from LU Appendix 1 of this standard; except where changes to the assets or their use, or new information, causes these failure rates to be invalid.

3.3.3.2 Where particular Signalling System assets are not covered by Appendix 1 of this standard, the Supplier shall define acceptable generic WSF and RSF failure rate limits caused by EMI, taking into account the contribution to the overall LU risk profile and reasonable System reliability requirements.

3.3.3.3 Any new or altered generic failure rate limits shall be endorsed by LU.

3.4 System characteristics

3.4.1 Identification of characteristics

- 3.4.1.1 The WSF immunity of the identified Signalling System shall be determined, over an appropriate frequency range, to encompass all credible threats. This shall consist of the levels and types of EMI necessary at defined ports to change the System state from a more restrictive to a less restrictive condition.
- 3.4.1.2 The RSF immunity of the identified Signalling System shall be determined over an appropriate frequency range to encompass all credible threats. This shall consist of the levels and types of interference necessary at defined ports to change the System state from a less restrictive to a more restrictive condition.
- 3.4.1.3 The Supplier of the Signalling System assets shall be responsible for the provision, validation and maintenance of any immunity data throughout the asset life-cycle. This requirement shall not apply retrospectively to information already contained within Appendix 1 of this standard unless the information becomes unreliable. This may result from either: changes to the Signalling System asset and/or its application, or the availability of new and accepted evidence.

3.4.2 Interference budgets

- 3.4.2.1 The Supplier of the Signalling System assets shall be responsible for the specification, validation and maintenance of immunity budgets to provide:
1. A safety margin for the mitigation of any uncertainties in the determination of the WSF and RSF immunity levels and;
 2. The apportionment of the various potential and existing EMI sources to ensure the System immunity is not exceeded when infrastructure modifications or changes occur.

Notes:

1. The Signalling System immunity is likely to be determined by a number of methods, which could include: testing, theoretical analysis/modelling, accepted engineering practice and the inspection of known information/data etc. Any methodology will undoubtedly involve tolerances, assumptions and in order to mitigate these uncertainties an interference budget must be determined, validated and applied, to provide a suitable safety margin;
2. Apportionment values are needed to ensure that any new and existing EMI sources are considered during the application of this standard. Any proposed change should not normally be allowed the full allocation of an immunity level because, for example, the current infrastructure configuration is already likely to have used up a portion and the combination, with the proposed change, may then pose a potential threat. It is therefore important to consider a wide range of scenarios, including:
 - (a) Existing infrastructure ambient/background EMI;
 - (b) Single and multiple train operation;
 - (c) Adjacent railways and infrastructure;
 - (d) Multiple sources of EMI.

- 3.4.2.2 The process of setting an interference budget shall be carried out by persons with appropriate expertise in the System concerned, and a suitably rigorous methodology shall be followed.



- 3.4.2.3 Supplier derived interference budgets shall be determined and endorsed by suitably competent persons and LU.
- 3.4.2.4 Any Third Party interference budgets shall be endorsed by a Network Rail (NR) accredited Independent Safety Assessor (ISA) and LU.

3.5 Transfer functions

3.5.1 General

- 3.5.1.1 The Supplier or Third Party responsible for the new or altered infrastructure shall determine transfer functions between that System and the identified Signalling System asset.
- 3.5.1.2 Supplier derived transfer functions shall be determined and endorsed by suitably competent persons.
- 3.5.1.3 Third Party derived transfer functions shall be endorsed by a NR accredited ISA.
- 3.5.1.4 The Supplier or Third Party shall provide all information reasonably requested for the determination of transfer functions.
- 3.5.1.5 Assumptions made regarding infrastructure parameters shall be expressly declared.
- 3.5.1.6 The Supplier or Third Party shall ensure that future changes to the infrastructure do not infringe the declared assumptions.
- 3.5.1.7 Derived transfer functions and any supporting test results and analysis shall be made freely available for the use of others in support of any other such LU activity.
- 3.5.1.8 Transfer functions shall assume pessimistic combinations of credible failures of both the new or altered infrastructure and the Signalling System. The level of pessimism shall be driven by the output of the risk assessment required by section 3.3.

3.6 Multiple sources

3.6.1 General

- 3.6.1.1 Where the new or altered infrastructure consists of more than one source of EMI, the Supplier or Third Party shall determine:
 - a) The maximum number of sources that can simultaneously generate interference;
 - b) Summation rules for these sources.
- 3.6.1.2 Suppliers shall provide all information reasonably requested for the determination of the maximum number of sources and summation rules.
- 3.6.1.3 The maximum number of sources and summation rules shall be endorsed by a competent person.



4 Responsibilities

1. The Surveillance Manager shall be responsible for ensuring that a co-ordinated programme of audit and inspection is implemented to assure that compliance with this and other related standards is ensured;
2. LU shall be responsible for incorporating the requirements of this engineering standard in any contract to which it is relevant and shall stipulate that a programme of audits are implemented by the supplier which ensures that these requirements are complied with. This programme and its results shall be available for verification by the LU Surveillance Manager;
3. The LU Professional Head of EMC (lulemc@tfl.gov.uk) shall be responsible for;
 - a) The review and acceptance of EMC Safety Cases;
 - b) Giving directions, where necessary, regarding identified Third Parties who do not comply with this standard;
 - c) Liaising with internal stakeholders to ensure the timely processing of data, information and submissions.
4. The LU Infrastructure Protection Manager shall be responsible for providing information about Third Party infrastructure about which LU is aware and liaising, when required, with other Professional Heads, suppliers and Third Parties;
5. Supplier/Third Party responsibilities include:

Item	Responsibility	Applicability
1	Demonstrating that the residual risk is ALARP	Supplier/Third Party
2	Demonstrating that the requirements of this standard have been met under normal and credible failure conditions	Supplier/Third Party
3	Attendance at Safety Case reviews	Supplier/Third Party
4	Defining and collation of generic data (including immunity data) and generic failure rates for signalling assets	Supplier
5	Deriving transfer functions and summation rules	Supplier/Third Party
6	Identifying locations of new or altered assets	Supplier/Third Party
7	Identifying Signalling System in use at specific locations	Supplier/Third Party
8	Performing Hazard identification and risk assessment activities	Supplier/Third Party
9	Providing generic infrastructure data reasonably required to support/derive any transfer functions	Supplier
10	Providing site-specific information	Supplier
11	Provision of competent and independent resources	Supplier/Third Party
12	Requesting signalling equipment data and allocating the correct interference budgets	Supplier/Third Party
13	EMC Safety Case production, amendment, configuration control and ISA review	Supplier/Third Party

Note: Appendix 2 contains details of the LU Third Party acceptance & process requirements.

5 Supporting information

5.1 Background

5.1.1 Additional Electromagnetic Compatibility (EMC) requirements for Signalling System assets are also contained within the following LU standards;

- a) Electromagnetic Compatibility - S1222;
- b) Signalling and Signalling Control - Concept and Requirements S1196.

These standards define the management of EMC issues that could potentially affect the safe and reliable operation of Signalling System assets, and include test, certification and assurance requirements.

5.1.2 The expected users of this standard are those responsible for the introduction, modification, operation or maintenance of new or altered infrastructure operating in the Vicinity of LU Signalling System assets.

5.2 Safety considerations

This standard defines requirements for the management of interference to Signalling Systems. Failure to comply with these could lead to false operation of Signalling Systems with the potential for collision or derailment.

6 References

References in the text are made to latest editions unless specific editions are cited. Where references are made to other corporate engineering documents which are not yet published, existing documents shall be followed until new documents have been authorised for use.

Note: References to particular EU Directives and Regulations, Acts of Parliament, Statutory Instruments or Common Law are made only if the subject demands them. Users of engineering standards are bound by all the relevant requirements of the law, regardless of whether or not there is any reference to them in the standards.

6.1 Statutory documents

Document no	Title
Directive 2004/108/EC	of the European Parliament and of the Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC
SI 2006 No. 3418	The Electromagnetic Compatibility Regulations 2006
SI 2006 No. 599	The Railway and Other Guided Transport Systems (Safety) regulations 2006

6.2 British Standards

Document no	Title
BS EN 50126	Railway applications. The specification and demonstration of reliability, availability, maintainability and safety
BS EN 50238	Railway applications. Compatibility between rolling stock and train detection systems



6.3 Other national standards

Document no.	Title
IEC 60050 (161)	International Electrotechnical Vocabulary (IEV) - Chapter 161: EMC

6.4 Industry codes of practice

Document no.	Title
Issue 1	International Handbook for Engineering Safety Management - Volume 1, Principles and Process
Issue 1	The principles of the safe management of engineering change: Guidance (RSSB document)
NR/GN/SIG/50007	HVI Network Rail Code of Practice
NR/GN/SIG/50008	EBI 200 Network Rail Code of Practice
NR/GN/SIG/50011	Axle counter Network Rail Code of Practice

6.5 LU company documents

Document no.	Title
S1222	EMC
S1196	Signalling and Signalling Control - Concept and Requirements
S1521	Safety Decision Making
S1538	Assurance
1-526 (S1526)	The Assessment and Management of HS&E Risk
S1622	Glossary of terms and abbreviations

6.6 Abbreviations

The following abbreviations are created:

- a) within London Underground's Glossary of Terms S1622;
- b) from published sources that are clearly identified.

Abbreviation	Definition	Source
ALARP	As Low As Reasonably Practicable	a
APR	Absolute Position Reference	a
ATO	Automatic Train Operation	a
ATP	Automatic Train Protection	a
BS	British Standard	a
CAU	Code Acceptance Unit	a
CBTC	Communication Based Train Control	a
CSDE	Correct Side Door Enable	a
DEV	Double Element Vane	a
EC	European Community	a
EMC	Electromagnetic Compatibility	a
EMI	Electromagnetic Interference	a
EP	Electro Pneumatic	a
FSK	Frequency Shift Keying	a
HVI	High Voltage Impulse	a
IEC	International Electrotechnical Commission	a
IEV	International Electrotechnical Vocabulary	a
ISA	Independent Safety Assessor	a
JTC	Jointless Track Circuits	a
LU	London Underground	a
NR	Network Rail	a
PAC	Passenger Access Control	a
PFI	Private Finance Initiative	a
RSF	Right Side Failure	a
RSSB	Rail Safety and Standards Board	a
SAP	Safety Acceptance Panel	a
S&CS	Signalling and Control Systems	a
SEV	Single Element Vane	a
SI	Statutory Instrument	a
TBTC	Transmission Based Train Control	a
TFU	Track Feed Unit	a
TTU	Track Termination Unit	a
WSF	Wrong Side Failure	a

6.7 Definitions

The following topic specific definitions are created:

- a) within the engineering function and are listed in S1622;
- b) from published sources.

Term	Definition	Source
Affected	Descriptive of that part of an LU route or infrastructure on which signalling asset(s) is within the Vicinity of a new or altered System	a
Broadly Acceptable	Level of residual risk regarded as insignificant and further effort to reduce risk not likely to be required as resources to reduce risks likely to be grossly disproportionate to the risk reduction achieved	a
Change	When new, or modified infrastructure or rolling stock, whether operating on or adjacent to LU infrastructure, that may present a credible EMI threat to LU Infrastructure	b
Electromagnetic Compatibility	The ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbance to other equipment in that environment	b - SI 2006 No 3418
Electromagnetic Disturbance	Any electromagnetic phenomenon which may degrade the performance of equipment. An electromagnetic disturbance may include: (i) electromagnetic noise, (ii) an unwanted signal, or (iii) a change in the propagation medium itself.	b - SI 2006 No 3418
Electromagnetic Interference	Degradation of the performance of an equipment, transmission channel or System caused by an electromagnetic disturbance Note: The terms "electromagnetic disturbance" and "electromagnetic interference" designate respectively the cause and the effect, but they are often used indiscriminately	b - IEV 161-01-06
Engineering Change	Any alteration to an existing System, or the introduction of any new System, including operation and maintenance	a
Hazard	Anything with the potential to cause harm	a
Infrastructure	Any electrical, electronic, earthing, cabling System, rolling stock, power supply, train detection System, civil or track asset	a
LU route	A section of railway infrastructure for which LU is the Infrastructure Controller	a
Right Side Failure	A failure of a Signalling System that causes a system/sub-System to revert to a pre-defined 'safe state' which can cause partial or total loss of functionality	
Risk	The combination of the frequency, or probability, of occurrence and the consequence of a specified hazardous event	a



Term	Definition	Source
Safety Case	A suite of documents which records the evidence demonstrating EMC between the new or modified infrastructure, rolling stock, traction power supplies and train detection Systems for a specific route or specific railway network	a - BS EN 50238
Signalling System	The engineering infrastructure which controls the movement of trains, together with associated trackside and train borne sub-Systems, comprising two major elements: a) Vital Systems, for the safe routing, spacing and speed control of trains; & b) Control Systems, whose failure poses no direct danger of a train movement accident	a
Submitter	The party responsible for producing the safety argument for acceptance by the LU SAP. If not the owner of the new or modified equipment, then it is agent thereof that has accepted the responsibility from the owner for providing technical assurance to LU	b
Supplier	Supplier to London Underground, the primary organisation or individual that is selected to deliver a product, service or facility to London Underground. This includes Consultants, Contractors, Internal Projects and PFI Contractors and excludes organisations or individuals selected by and contracting directly to them	a
System	A combination of engineering assets or services, or both, and end users placed together or arranged in a regular and connected whole	a
Third Party	Descriptive of an organisation other than LU or a Supplier	a
Vicinity	Zone in which new or altered infrastructure, is capable of causing EMI to LU signalling assets, where the distance from the source shall be taken as not less than 500m or there is a credible conductive EMI path	a
Wrong Side Failure	A failure of a vital component or sub-System which produces an output which is potentially unsafe	a



6.8 Person accountable for the document

Person accountable for the document
John Bradshaw - The Professional Head of EMC

6.9 Document history

Issue no	Date	Changes	Author
R9	July 2007	Standard 2-01016-001 re formatted and re-numbered to 1-193, no technical changes have been made to the content other than changing references to other Standards where their numbers have changed	-
A1	October 2007	Authorised for use. Previous authorisation is valid	-
R10	December 2008	Incorporating WN/00764	-
1-193 A2	February 2009	Authorised for use	-
S1193 A3	March 2013	Reformatted, renumbered and updated as detailed in DRACCT submission No 01441	John Bradshaw & Peter Price

7 Appendix 1 – Track circuit immunity

7.1 Introduction

Electromagnetic Interference exists within all LU infrastructures and this can cause failures and erroneous operation of Systems with serious effects for both safety and reliability. Any System design must therefore address EMI, the required levels of immunity and ultimately ensure that EMC is achieved ensuring any System will operate as designed, will not adversely affect other Systems, or be susceptible to malfunction due to the LU electromagnetic environment. LU Standard S1222 specifies the requirements for EMC, identifying “LU Specific Needs” which are not covered by the EMC Directive and the BS EN50121 series of railway standards.

7.2 Purpose

The purpose of this Appendix is to specify signalling immunity requirements which are not covered by BS EN50121 and to provide guidelines on the maximum allowable levels of interference on the railway. This document must be read in conjunction with the particular specification for the individual Signalling equipment.

7.3 Scope

This Appendix applies to all train borne and line-side vital Signalling equipment, wayside non-vital Signalling Systems, control Systems, station and wayside Signalling communications Systems fitted within LU.

It does not cover track circuits used on adjacent railways.

7.4 Potential EMI sources

7.4.1 Rolling Stock

Modern DC trains have high power traction and auxiliary inverters which take power from the traction rails via conducting shoes.

Inverters generate significant amount of EMI levels which are filtered within the train to minimise interference currents appearing on the rails. Train generated interference which appears on the LU traction rails is generally referred to as “Differential Mode Current” (I_d) and interference which appears on the running rails as “Common Mode Current” (I_c).

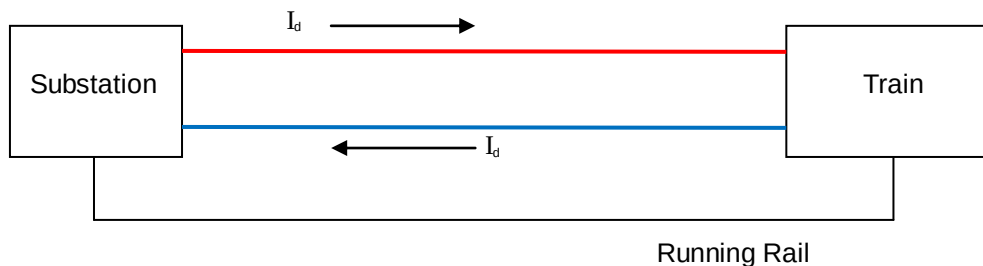


Figure 1 - Differential mode current paths

Common mode current occurs because of AC currents flowing from the traction rails through the train filters and stray capacitance internal to the train to the train chassis/earth and onto the running rail via wheel contact.

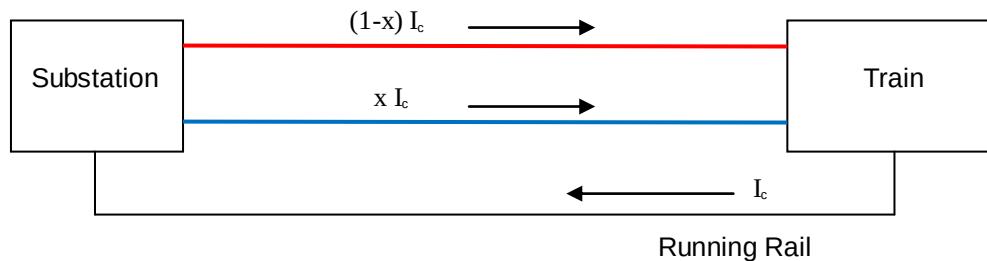


Figure 2 - Common mode current paths

The traction rails have gaps in them, particularly at points, crossings and substations. Significant arcing can occur at these gaps generating high levels of radiated EMI.

Rolling Stock can have a variety of intentional transmitters on them. These may pass very close to trackside Systems and expose them to high levels of field strength.

7.4.2 Substations

The rectification process in a substation creates an AC voltage ripple on the 630V DC traction supply. The train(s) impedance across this voltage creates a current which appears in the traction rails.

7.4.3 Adjacent Railways

Interference created by trains on an adjacent railway will, in general, couple into track circuits on the LU Line. Adjacent railways include Network Rail, High Speed 1, Docklands Light Railway, London Tramlank and other adjacent LU Lines.

Depending on the nature of the interface the coupling factor can vary significantly.

7.4.4 Interference Coupling

This can take several forms and the more critical ones are described below.

7.4.4.1 Inductive

Current flowing in the loop created by the LU traction rails will inductively couple into the track circuit loop formed by the track circuit receiver, running rails and transmitter/train axle.

Current can also be induced into the track circuit loop from adjacent railway traction Systems.

Similarly currents can be induced into cables, affecting line-side or equipment room signalling.

7.4.4.2 Conductive

A percentage of any EMI currents which flow in the running rails will flow through the track circuit receiver. These can be as a result of train common mode current, fault paths or conductive paths from adjacent railways.

7.4.4.3 Faults

Fault conditions that may change the normal coupling or interference magnitude shall be considered (e.g. a short circuit between the traction and running rails, a failed insulated block joint, a broken rail, bond or a failed train EMI filter, etc).

7.5 Immunity limits

7.5.1 General

Any EMI sources when coupled into the Signalling System shall not exceed the immunity limits specified in this section. All modes of operation of the relevant infrastructure (i.e. the operation of trains, sub-station and power equipment etc) shall be considered.

Where there is more than one source of EMI, any applicable limit(s) must be apportioned between the various sources (e.g. source 1, 09TS - source 2, NR - source 3, HS1- source 4, power equipment, ambient levels, etc.) to ensure compliance is achieved.

Note: Apportionment values of around 20 to 33% have been successfully applied in the past but the supplier must justify whatever value they use.

Where more than one in-band frequency is present the permitted level shall be decreased in accordance with Section 7.29.

Where it is required to interpolate between frequencies the method detailed in Section 7.30 shall be used unless otherwise stated.

The actual track circuits that need to be assessed will, of course, depend on the location and scope of the work and are likely to be only a subset of those listed here.

With the ever evolving nature of the LU infrastructure users of this standard must **always** check/clarify, exactly, which signalling they need to assess in their EMC Safety Case and never make simple assumptions. An example being that some legacy track circuits have been retained on the upgraded Jubilee and Victoria Lines.

This Appendix does not set any immunity limits for EMI from intentional transmitters. This should be assessed using the requirements from LU standard S1222 and guidance document G222.

7.5.2 Non compliance

If the requirements of this Appendix cannot be met it may still be possible to demonstrate EMC by the use of operational restrictions, controls or more detailed System information. The following are examples of additional mitigation.

- 1) There are 5 different types of Delta track circuit used within LU, each with slightly different immunity limits. Where it can be proven that the specific type in use is compatible, providing operational restrictions and controls are put in place to exclude the other types, EMC can then be demonstrated;
- 2) The immunity of a track circuit is related to its length. Where the specific length(s) are shorter than the stated generic longest length and it can be then proven to be compatible, because the immunity levels have been adjusted, and controls are put in place to prevent the use of longer track circuits in future, EMC can then be demonstrated;
- 3) In certain infrastructure layouts it is not possible to achieve the combined traction current from multiple trains. Where this can be demonstrated the EMI apportionment could be relaxed.

The use of any of the above mitigations must be approved via the concession process.

Where no immunity data is given in this Appendix, none is currently known. LU and the appropriate System manufacturer must be consulted to obtain susceptibility limits.

7.6 Mean Time Between Failures

Exceeding any of the interference levels quoted could result in malfunction of the signalling.

The Supplier shall inform LU of any known failure modes of the electrical System which could occur and give rise to false energisation of the track circuit (i.e. WSF indicating that the track is unoccupied). The Supplier shall also demonstrate that the mean time between WSF of the track circuit caused by such System failure modes shall not be less than 10^9 hours.

The Supplier shall inform LU of any known failure modes of the electrical System which could occur and give rise to false energisation of a line-side circuit, relay or valve. This shall also demonstrate that the mean time between WSF of the line-side circuit, relay or valve caused by such System failure modes shall not be less than 10^9 hours.

The Supplier shall inform LU of any known failure modes of the electrical System which could result in false de-energisation of the track circuit (i.e. a RSF indicating that the track is occupied). They shall also demonstrate that the mean time between RSF, of the track circuit, caused by such System failure modes shall not be less than 10^6 hours.

7.7 $33\frac{1}{3}$ Hz Double Element Vane (DEV) track circuits

7.7.1 Technical Description

This track circuit employs insulated rail joints in one running rail (referred to as the section rail) in order to provide isolation from adjacent track circuits. This rail is normally furthest away from the positive traction rail. The other running rail forms a continuous conductor (referred to as the continuous rail) and is normally adjacent to the positive rail. In situations where the positive traction rail changes sides (at station platforms for example), or where an anti-opposition track circuit is implemented, the section rail may be adjacent to a positive traction rail. (An anti-opposition track circuit is one where the section rail and the continuous rail swap sides and both rails have an insulated joint. In this situation electrical continuity of the continuous rail is maintained by a cross bond from the end of one rail to the start of the next on the opposite side).

The device used to detect track circuit occupancy is a $33\frac{1}{3}$ Hz Double Element Vane Relay. Excitation is required to be present on two windings with a phase displacement in order to detect track circuit unoccupied. The control winding is fed by a local supply at a frequency of $33\frac{1}{3}$ Hz. The track winding is fed with an out of phase signal taken from across the rails at the entry point of the track circuit. The exit end of the track circuit is fed from the same local supply via an adjustable capacitor that provides the required phase shift. This capacitor also has the functions of setting the track energisation to compensate for leakage paths and of blocking DC current in the circuit. The presence of a train shunts the current flowing in the track winding and de-energises the relay. If any interference current with the necessary amplitude, duration and frequency is coupled into the track circuit, the relay may be unsafely energised.

The maximum length track circuit is 1,000 m.

7.7.2 Interference immunity characteristics

The maximum permitted level of EMI is shown in Table 1. For each discrete frequency at which the relay is sufficiently responsive for a Hazard to exist, a value of maximum current in the running rail and traction rail is provided. The values define a current envelope which must not be exceeded by an interfering signal.

The “running rail” limit can also be considered to be the limit for current in the DEV Track Coil (Limit assumes worst case 100% coupling from rail to coil).

7.7.3 Relaxations for short duration pulses

The maximum permitted levels of electrical interference for durations between 50 ms and 200 ms are shown in Table 2. The values given define a current envelope which must not be exceeded by an interfering signal with the corresponding duration. LU may be prepared to allow higher currents for durations shorter than 50 ms. The Supplier should seek advice from the LU Professional Heads of Signalling and EMC under such circumstances.