Manual of Good Practice

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London Underground

Manual of EMC best practice

Contents

A Manual of Good Practice is defined as:

A document which provides guidance on how to apply, interpret or achieve the requirements of engineering standards.

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1 Introduction

1.1 This document describes the philosophy that must be adopted when designing, selecting, specifying, commissioning and inspecting electrical installations on London Underground premises for the purpose of achieving electromagnetic compatibility in the final installations.

1.2 High quality assurance and design standards must be adopted in the application of this philosophy.

2 Scope

2.1 This Manual of Good Practice is aimed at:

a) defining and clarifying the key EMC requirements for all types of new, modified and 'off the shelf' systems into one document to ensure that the supplied system meets the ED 'Essential Requirements';

b) providing guidance to Project Engineers on the applicable standards covering frequency limits of emissions and susceptibility;

c) defining the requirements for the EMC Control Plan, Test Plan and Test Reports.

2.2 Electromagnetic Compatibility (EMC) requires that all systems operate in a safe manner and perform their intended function, and that the operation of a given system does not degrade the performance of any other systems. Although EMC is not specifically safety related, it is an important aspect of providing railway systems which will operate both safely and reliably. The requirements set out in this document are a means of providing assurance to the Engineering Directorate (ED) that the 'Essential Requirements', which are explained further in Section 3, will be achieved when any equipment or system is installed and operated on the London Underground infrastructure. This assurance will support the ED in its duty to comply with various statutory obligations particularly with regard to the acceptance and commissioning of assets.

2.3 Collating and updating the EMC requirements within one document will ensure that a correct and consistent approach is taken by all engineering disciplines, EMC is addressed at all stages of a system life cycle and the risk of specifying redundant or inappropriate requirements is reduced. It is also important to ensure these requirements are addressed at the initial stage of a contract so that assurance can be demonstrated before the system is installed and commissioned. Waiting until the system is on line to consider EMC issues is not acceptable and is likely to lead to costly service delays and disruption. The project manager must ensure the requirements of this document are implemented and must contact the ED to confirm the scope of requirements at an early stage.

2.4 This standard replaces 5-01018-001. The Standard has been re formatted and re-numbered. There were no technical changes.

3 Guidance

3.1 Technical Background

3.1.1 Any electrical or electronic equipment has the potential to cause EMI if not correctly designed, manufactured or installed. In the LU operational environment a large number of critical, emissive and sensitive systems are co-located in close proximity, including similar systems used by other rail operators and external organisations. This scenario results in one of the most difficult and challenging types of EMC environments in which a system must operate. The need to address and manage the EMC requirements throughout a system life cycle (e.g. from the initial ITT stage to the final system installation and ongoing maintenance) is of paramount importance if the total system EMC is to be achieved and maintained.

3.1.2 Achieving EMC for the wide range of LU equipment and systems is interpreted as reducing the likelihood of unacceptable interference occurring between constituent parts and between LU installations and the outside world, including other rail operators. This must be achieved at an acceptable cost, commensurate with demanding safety requirements. The accepted method of achieving this is to impose design, analysis and testing constraints on equipment and systems within a rigid framework of ongoing EMC management and quality control procedures.

3.1.3 The choice of test limits and installation constraints must in the first instant be based upon previous experience. Fortunately, the choice of tests, test limits and acceptance criteria present within current specifications are themselves derived from cost effective considerations. Careful selection of these criteria followed by careful monitoring of equipment development, integration and installation, will reduce the risks of incompatibility.

3.1.4 Foremost of the special considerations imposed by railway systems must be the effects of interference on existing and new safety systems which also includes internal LU aspects. This is of particular concern when interference could, for example, lead to a wrongside failure of signalling equipment and the opening of train doors whilst the train is in motion, with unacceptable safety implications. In this respect testing and analysis must be conducted within the framework of reliability and of equipment failure modes which could give rise to unacceptable interference levels and margins.

3.1.5 Apart from direct considerations of the effects of interference on safety systems the approach, in general, is to consider interference as arising from the normal functioning of equipment, and does not address failure modes explicitly.

3.1.6 Of paramount importance to the LU business perspective must be the possible impact of EMC on the Customer and the latter's perception of the service offered. It is also important that normal consumer products, such as portable computers and games, which themselves are required to be tested for immunity to interference, are not adversely affected by LU facilities. Considerable care needs to be taken to ensure that such high profile Customer facilities as CCTV, PA systems and help points are of high quality. Any electrical or electronic equipment has the potential to cause EMI and the risk should be determined on its design status and not on its proposed usage.

3.2 The ED Essential Requirements

3.2.1 The essential Requirements detail the minimum level of assurance required by the ED before a system is commissioned and meeting them will support the ED in its duty to comply with various statutory obligations.

3.2.2 All electrical and electronic equipment installed on the LU network should:

a) not cause electromagnetic interference under normal and failure operating conditions.

b) operate correctly, without degradation of quality, performance or loss of function within the electromagnetic environment in which it is to operate under all normal operational and failure conditions.

3.2.3 It should be noted that the BS EN 50121 series of Railway EMC standards contains many of the requirements set out in this document. However, because of the special characteristics of the LU and surrounding environment, additional requirements are required (e.g. to address "special cases" unique to LU and to address gaps within the standards) to ensure the total threat is considered and mitigated.

3.3 EMC Strategy

3.3.1 Background

EMC is not a new requirement for the many diverse types of electrical and electronic equipment and systems that form part of the LU network. The requirements are generally well established and have been incorporated in various ED standards for many years. The EMC Directive has also helped to define and clarify EMC issues and raise the profile of EMC within LU and to contractors since its full introduction in January 1996. However, various problems have occurred, which this document aims to resolve:

a) incorrect interpretation and implementation of EMC requirements into contractual documentation, resulting, in some cases, in the omission of EMC requirements;

b) delays in the ED approval process when inadequate assurance has been presented or relevant information was unavailable;

c) EMC problems causing reduction in system reliability and availability, and rework.

3.3.2 Strategy for Compliance

3.3.2.1 Normally all equipment and systems procured for LU should meet the requirements listed below in Section 5. The strategy is largely based on compliance with the BS EN 50121 series of Railway EMC Standards in conjunction with additional requirements needed to:

a) address 'special' cases unique to LU.

b) address limitations with the standards.

c) ensure that the installed systems, and not just individual equipment, are EMC.

3.3.2.2 A system or equipment that does not contain electrical or electronic devices will not need to meet all of the test requirements listed below. Further advice should be requested from the ED in such cases.

3.3.2.3 System Level Compatibility

This can be achieved by ensuring that:

a) EMC is addressed throughout the system life cycle from the initial design through to on-site maintenance.

b) the individual system equipments meet the standards by testing in the worst case configuration.

c) the system is installed in a manner that will ensure EMC is achieved by using appropriate cable types, good earthing and bonding methods, equipment separation, and cable routing and segregation schemes.

3.3.2.4 Process

3.3.2.4.1 The requirements in this document should take precedence over any other similar requirements detailed in complementary ED standards. The project manager is responsible for all aspects of the implementation of this document and ensuring the required level of assurance is presented to the ED.

3.3.2.4.2 The project manager should ensure that:

a) these requirements are included in the ITT, contract and specification;

b) a competent person is appointed who confirms that all the applicable requirements are included in the ITT;

c) the need for the contractor to provide evidence of compliance is specified;

d) any evidence of compliance is reviewed and validated by a competent person;

e) any differences between submitted items of evidence for compliance are resolved;

f) he is able to provide assurance to the ED that the system meets these EMC requirements;

g) the chosen contractor has the required level of competent and approved staff to meet the ED requirements;

h) any requested documentation is made available to the ED, for review during the approval and assurance processes;

j) a Declaration of Conformity is issued to the ED;

k) the requirements are recorded and managed using a requirements management software tool, to allow their status and history to be reviewed by the ED.

3.3.2.4.3 A formal submission to the LU SAP may be required for some systems. The project engineer should contact the ED to determine any such requirements.

3.3.3 Off-the-Shelf and Previously Approved Systems

3.3.3.1 Procuring some systems for direct compliance with the new EMC Railway Standards may not be possible. For example, a proposed system may already satisfy a product or generic standard (e.g. BS EN 50082-2), or a previously approved system specified for a new installation could already meet many of the individual test requirements set out in the railway EMC standards. Expecting these systems to be revalidated would be expensive and not commercially viable.

3.3.3.2 Previous evidence of compliance may be acceptable to the ED provided it is possible to demonstrate and verify that the current approval status is equivalent to or exceeds the applicable worse case ED requirements set out in this document.

3.3.3.3 The Project Engineer should ensure that all such evidence is available and has been reviewed and validated by a competent person. The contractor will be required to supply all data requested by LU (e.g. previous test results, test reports, hardware or firmware changes between previously tested and supplied system) to verify the requirements detailed in this document have been met.

3.3.3.4 Any differences between the submitted evidence and these requirements may require additional analysis and test to resolve. Assurance must be given that the associated system satisfies the ED essential requirements. The Contractor should carry out any additional work required when previous tests or the content of any document are not considered adequate by LU.

3.3.3.5 The project engineer must ensure that the contractor is made aware of the railway EMC environment to ensure a system, which may be 'CE' marked for a domestic environment, cannot be incorrectly specified for use by LU.

3.3.4 Modified Systems

3.3.4.1 Assurance is required that the ED EMC Essential Requirements have been met when any existing systems are modified or a major retrofit has been performed.

3.3.4.2 As a minimum, an analysis must be performed (e.g. using the EMC test data for the new system or sub-system and the use of approved EMC installation practice) to demonstrate that the addition of the new system or the retrofit programme has not degraded the current level of EMC. Direct equipment replacement may not need any significant analysis. The level of analysis will depend on the scope of the proposed modification as it is difficult to generalise on the assurance needed for all possible types and levels of modification that could occur. The degree of assurance required by the ED should be agreed at an early stage by the project.

3.3.4.3 Any differences between the submitted evidence and these requirements may require additional analysis and test as requested by the ED. Assurance must be given that any such system satisfies the ED Essential Requirements.

3.3.4.4 A formal submission to the LU SAP may be required for some systems. The project engineer should contact the ED at an early stage to determine if this is required.

3.3.5 Systems not Included in the EMC Railway Standards

3.3.5.1 Not all systems currently used by LU are included in the BS EN 50121 series of standards. These systems (e.g. lifts, escalators, UPS, UTS, computer networks and information systems) should meet the minimum requirements set out in the appropriate product standard and Attachment 1 of this document. Additional requirements may be required if a formal submission to the LU SAP is needed.

3.3.5.2 Any differences between the submitted evidence and these requirements may require additional analysis and test as requested by the ED. Assurance must be given that any such system satisfies the ED 'Essential Requirements'.

3.3.5.3 A formal submission to the LU SAP may be required for some systems. The project engineer should contact the ED at an early stage to determine if this is required.

3.3.6 Railtrack Requirements.

3.3.6.1 Additional requirements will be needed if the proposed system could impact on any Railtrack or other rail operator infrastructure. The majority of these are similar to the ED requirements contained within this document and the project engineer should contact the ED for further details. The degree of involvement must not be under-estimated since Railtrack have a large number of internal standards and they will expect assurance that the new system will not cause any EMC issues.

3.3.6.2 The main area to be resolved at an early stage is the submissions that may be required by the Railtrack SRG (Safety Review Group). This process can cause significant cost overruns and delays if they have not been correctly included in a project programme plan.

3.4 The ED EMC Requirements.

3.4.1 The system must satisfy the ED requirements by meeting all the standards, test and documentation requirements listed in this section. Both normal operating and credible operational conditions must be considered when any evidence of compliance is presented to the ED.

3.4.2 The project manager should contact the ED at an early stage to ensure that all the applicable requirements are included in the ITT document. This initial contact will be very important particularly if the proposed system will have to provide submissions to the LU SAP or if the proposed system could have an impact on any Railtrack or other rail operator infrastructure. Any omissions must be approved by the ED before acceptance is requested.

3.4.3 Railway Standards

BS EN 50121-1, Railway applications - Electromagnetic Compatibility, Part 1: General. This part gives a description of the electromagnetic behaviour of a railway and specifies the performance criteria for the whole set of standards.

BS EN 50121-2, Railway applications - Electromagnetic Compatibility, Part 2: Emission of the whole Railway to the outside world.

BS EN 50121-3-1, Railway applications - Electromagnetic Compatibility, Part 3-1: Rolling Stock - Train and complete vehicle.

BS EN 50121-3-2, Railway applications - Electromagnetic Compatibility, Part 3-2: Rolling Stock - Apparatus.

BS EN 50121-4, Railway applications - Electromagnetic Compatibility, Part 4: Standard for the Emission and Immunity of the Signalling and Telecommunications apparatus.

BS EN 50121-5, Railway applications Electromagnetic Compatibility, Part 5: Fixed power supply installations.

Notes:

a) The minimum levels of radiated and conducted immunity should be 10V/m and 10V respectively.

b) Class B Radiated Emissions may be required for systems that will operate within 10m of a communications receiver.

c) Class B Conducted Emissions may be required for systems whose supply is obtained from an REC.

BS EN 50155 - Railway applications. Electronic equipment used on rolling stock.

BS EN 50238 - Compatibility Between Rolling Stock and Train Detection Systems.

EMC requirements for systems and equipment not included in the above are detailed in Attachment 1.

3.4.4 Additional Requirements not included in BS EN 50121

3.4.4.1 All systems connected to a dc supply must also meet the requirements of the following standard.

BS EN 61000-4-16, EMC, Test for Immunity to Conducted, Common Mode Disturbances in the Frequency Range 0-150 kHz.

3.4.4.2 All systems connected to a mains supply must also meet the requirements of the following standards:

BS EN 61000-3-2, EMC, Limits for harmonic current emissions (equipment input current ≤ 16 A per phase).

BS EN 61000-3-3, EMC, Limitations of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current ≤ 16 A per phase.

BS IEC 1000-3-5, EMC, Limitations of voltage fluctuations and flicker in low voltage supply systems for equipment with rated current >16 A per phase.

BS EN 61000-4-16, EMC, Test for Immunity to conducted common mode disturbances in the frequency range 0-150 kHz.

BS EN 61000-4-11, EMC, Voltage dips, short interruptions and voltage variations immunity tests.

3.4.4.3 Interface Issues

It is essential that throughout the design and installation process the contractor(s) liaise with LU to design and develop systems, in conjunction and co-operation with the designers of interfacing systems. This issue can be addressed by the requirement to hold review meetings.

3.4.4.4 EMC Review Meeting

The requirements for these meetings must be specified in the contract and the contractor(s) should be required to support them as and when requested by LU. The meeting should be held at least bi-monthly at a central London location to review progress, test requirements, failures, interface issues and areas of concern etc. An EMC representative from each contractor should attend, together with any other LU representatives required. The exact scope can be determined at the initial meeting.

3.4.4.5 Doors Open

The System should be tested in the worst case conditions for immunity. Where doors, panels, and covers are removable during on site maintenance, these should be removed or opened during the appropriate immunity tests, to identify and assess the significance of any failures arising, and devise mitigating measures where necessary.

3.4.4.6 System Level Testing

3.4.4.6.1 System Integration tests may also be required to demonstrate that a system is EMC with other systems. These tests may be particularly important when a number of emissive and sensitive systems are co-located (e.g. station platform area).

3.4.4.6.2 Tests may consist of on-site measurements and mutual interference trials, examining the operation of one system and the monitoring of another to observe any interference problems.

3.4.4.7 Special cases

3.4.4.7.1 A Special Case is defined as an EMC threat which is unique to LU and has not been addressed in the above standards.

3.4.4.7.2 The Project Manager should ensure that any such special cases are identified at an early stage by performing a hazard analysis for the proposed system. The potential impact of these threats should be avoided, if possible, by utilising approved EMC design and installation practice.

3.4.4.7.3 Examples of these cases are:

a) a system installed adjacent to or under a high voltage power line and therefore requiring additional protection from increased levels of electric and magnetic fields. BS IEC 61000-2-7, Section 7 gives guidance on low frequency magnetic fields from various environments. See also LU documents 1-194 to 1-201 in connection with 25 kV overhead systems.

b) a system installed adjacent to a power transformer or cable, requiring additional protection from increased levels of magnetic fields, surges and transients.

c) a system installed adjacent to an airport (the threat from high power radar may need to be considered).

d) a system installed adjacent to a communications transmitter (the system may need additional protection from increased levels of electric field).

e) a system installed near a communications receiver (which may therefore have to comply with Class B emission levels).

Test requirements from the following standards may be required to assess and mitigate the above threats and the project engineer should ensure a competent person reviews and determines the exact requirements. Specialist advice will be required, from the ED, for these cases.

BS EN 61000-4-9, EMC, Pulse magnetic field immunity test.

BS EN 61000-4-10, EMC, Damped oscillatory magnetic fieldimmunity test.

BS EN 61000-4-11, EMC, Voltage dips, short interruptions and voltage variations immunity tests.

BS EN 61000-4-12, EMC, Oscillatory Waves Immunity Test

BS EN 61000-4-16, EMC, Test for Immunity to conducted, Common Mode Disturbances in the frequency range 0-150 kHz.

BS EN 61547, Equipment for General Lighting Purposes, EMC Immunity Requirements.

BS IEC 1000-2-6, Electromagnetic compatibility (EMC), Assessment of the emission levels in the power supply of industrial plants as regards low frequency conducted disturbances

BS IEC 1000-3-6, EMC, Assessment of emission levels for distorting loads in MV and HV plant.

BS IEC 1000-3-7, EMC, Assessment of emission levels for fluctuating loads in MV and HV plant.

BS IEC 1000-2-7, EMC, Low Frequency magnetic fields in various environments.

BS IEC 1000-3-8, EMC, Guide to signalling on low voltage electrical installations, emission limits, frequency bands and electromagnetic disturbance bands.

3.4.5 ITU Requirements - Touch Voltage Study

3.4.5.1 A study is required to show that the ITU levels for touch voltage, induced on cables and any exposed metalwork, will not be exceeded.

3.4.5.2 The system installation techniques (earthing system, bonding and cabling methods etc) should prevent any longitudinal and transverse voltage from exceeding:

a) Continuous 25V rms

b) Non-continuous (fault conditions) 430V rms.

On-site testing may be required to validate the outcome of this study.

3.4.6 Psophometric Noise

3.4.6.1 A study should be performed to show that the ITU levels for psophometric noise are not exceeded. This type of study is important to ensure that any potentially susceptible equipment (e.g. tunnel telephones) is immune to low frequency emissions not addressed by the railway and product EMC standards.

3.4.6.2 The psophometrically weighted value of the current should be computed using root-sum-squares of individual harmonics using ITU telephone weightings.

3.4.6.3 Psophometric Current = ($\sum (I_n P_n)$ $^1/_2$ where the weighting factor Pn is determined by the relative sensitivity of the human ear to various frequencies.

3.4.6.4 The system should not give rise to a psophometrically weighted transverse noise voltage in excess of 1 mV.

3.4.6.5 In order to protect the communications telephone system the maximum psophometric weighted noise current should be limited to 5.5 A per train, with a design target of 5.0 A.

3.4.7 DC and Low Frequency Magnetic Field

For train saloons the maximum dc level should be 1 mT up to 600 mm from the floor and 0.5 mT elsewhere. The maximum rms level at 50 Hz should be 0.1 mT throughout the saloon.

3.4.8 Signalling Compatibility

3.4.8.1 A formal submission will be presented to the LU SAP for review and approval. The project engineer should contact the ED, at an early stage, to confirm the type and format of documentation that will be needed before acceptance of the system can occur.

3.4.8.2 Assurance may be required to show that that the system will satisfy the requirements of ED Document 1-193. The project engineer should contact the ED to confirm that the appropriate items have been included in any analysis or test programme. The following LU documents are also relevant in this regard:

1-194	Signalling Control - Functional Requirements
1-195	Signalling - Functional Requirements
1-196	Signalling and Signalling Control - Concept and Requirements
1-197	Signalling and Signalling Control - Design and Implementation
1-198	Signalling and Signalling Control - Installation, Testing, Commissioning and Handover
1-199	Signalling and Signalling Control - Operation and Maintenance
1-200	Signalling and Signalling Control - Alterations to Systems
1-201	Signalling and Signalling Control -Approvals

3.4.8.3 Background

3.4.8.3.1 The four rail insulated system used by LU requires that special consideration be given to the protection of low frequency operated signalling and communication circuits. These circuits are typically designed to operate over a narrow bandwidth centred on a specific frequency e.g. $33^1/_3$ Hz, 125 Hz, 62 kHz, 75 kHz (it should be noted that Railtrack track circuits operate at different frequencies for a submission to their SRG or RSAB).

3.4.8.3.2 The introduction of new electrical facilities to the LU system must address possible interaction with these devices to demonstrate that, for a minimum MTBWSF of 10^9 hours, no failure of the signalling device can be initiated by the normal or failure modes of the new equipment. Particular emphasis is placed on devices which could lead to a 'wrongside failure' indication.

3.4.8.3.3 The principal cause of such interference is the coupling of harmonic currents into the signalling device at or near the operating frequency, sufficient to cause false energisation of an occupied track circuit. Possible contributors to these harmonic currents, which must be considered, are rolling stock traction and auxiliary equipment, power supply ripple and power cable coupling.

3.4.8.3.4 Low frequency coupling paths for consideration are:

a) conductive coupling along the track supply rails and into the track circuits;

b) capacitive coupling between running rails, supply rails and the traction equipment, resulting from high rates of voltage change;

c) inductive coupling resulting from high rates of magnetic field and current change;

d) under-car equipment and cables and signal circuits;

e) parallel earth isolated circuits;

f) parallel conductors with common earth returns;

g) radiated coupling from transmitters and interference radiated in the far field.

3.4.8.3.5 The minimum MTBWSF of 10^9 hours requires that a rigorous study is performed on all the normal and failure coupling modes for each of the signalling circuits which may be affected.

3.4.8.3.6 The methods to be adopted fall into the following categories:

a) a high level Fault Tree Analysis (FTA) of all the possible failure modes which could give rise to signal failures, by the above coupling mechanisms;

b) failure Modes and Effects analysis (FMEA) and a reliability assessment of the equipment which could give rise to interference effects;

c) analysis of coupling effects and safety margins between the identified sources of interference and the signal circuitry;

d) the introduction of design measures such as filters and interference monitors to reduce the risks to acceptable levels;

e) complementary measurements to confirm the predicted levels of harmonics actually induced into the signal circuitry.

3.4.8.3.7 The following design proving techniques should be applied where signalling compatibility is considered to be at risk.

3.4.8.4 Hazard and Reliability Analysis

3.4.8.4.1 A hazard and reliability assessment should be conducted on all equipment connected to the traction supply to demonstrate that the following minimum reliability figures are achieved for a train.

3.4.8.4.2 Account should be taken of:

a) filter tolerances and failures;

b) infrastructure faults;

c) failure and combination of failures of components. Component changes due to ageing and environmental effects, all possible operating conditions of the equipment and supply, dormant failures. transient effects;

d) equipment safety considerations;

e) closed loop operation under steady state and transient conditions.

3.4.8.5 Failure Modes and Effects Analysis

3.4.8.5.1 A detailed failure mode and effects analysis should be conducted on the trainborne equipment to determine the possible effects of equipment and system failures on the safety of the track signalling system.

3.4.8.5.2 The analysis should identify all possible coupling modes and should be carried out to meet the requirements of the LU Engineering Safety and Hazards Manager as defined in LU Document D001-ESHM-90-0 'Principles and Process of Engineering Safety Analysis'. The corresponding document for Contractors is D009-ESHM-91-Z 'Principles and Process of Engineering Safety Analysis (Contractors Edition)'.

3.4.8.5.3 For the purpose of safety analysis, the failure modes considered should be those contained in ORE Directive 'Use of Electronic Components in Railway Signalling, Question A 155.3 Draft 5'.

3.4.8.6 Dynamic Train Tests

3.4.8.6.1 These tests should be conducted with a fully representative train running on an LU track and with all equipment installed.

3.4.8.6.2 The tests should be designed to fully exercise the traction equipment under all worst case operating conditions, whilst monitoring the emissions which could couple to:

a) track signalling;

b) other trainborne equipment;

c) trackside communication and signalling equipment.

3.4.9 Testing

3.4.9.1 Tests and inspections should be carried out for the purpose of verifying design, ensuring proper performance, safety, reliability, and compliance with this document.

3.4.9.2 Tests and inspections should be conducted in accordance with the requirements set out within this document.

3.4.9.3 LU should be granted free access to inspect any item of equipment at any time, at any of the Contractor's manufacturing and assembly plants.

3.4.9.4 LU should have the right to witness any tests and be given free access to any facilities where installation, cut-over work or tests are in progress and to all inspection and test records.

3.4.9.5 At least 14 days notice should be given of any proposed test dates.

3.4.9.6 LU should have the right to take over control of the testing if it is determined that the Contractor is unlikely to complete the work on time. The costs incurred by the Engineer for such testing should be charged to the Contractor.

3.4.9.7 The installation and testing of equipment by the Contractor should allow for close monitoring by LU.

3.4.9.8 Ample time should be allowed within all testing programmes for alterations to equipment, systems and designs to be carried out, together with all necessary re-testing prior to final commissioning.

3.4.9.9 All tests which affect the normal operation of the existing railway should be conducted so as not to impact on the operations or compromise safety.

3.4.9.10 The Contractor should conduct all tests in accordance with the approved test procedure, except as otherwise specified, furnish all labour, materials and equipment necessary to perform tests, record data and prepare reports. Tests should demonstrate compliance with the requirements of the Contract. Any changes required to bring the system into compliance should be carried out by the Contractor at no additional cost to LU, including the costs for repeat testing.

3.4.9.11 It should be the Contractor's sole responsibility to organise and conduct each test as required.

3.4.9.12 All test reports and test result data sheets should be signed by an approved member of the Contractor's staff.

3.4.9.13 A test report in accordance with Attachment 5 will be issued to LU for approval.

3.4.10 Instructions for Use of the system.

3.4.10.1 These instructions and their implementation are essential to achieve system EMC. The EMC Directive stipulates that all apparatus must be accompanied by instructions containing all the information required to use the apparatus for its intended purpose in the defined electromagnetic environment. These instructions will provide the necessary information required to install and commission the system, and to ensure no problems are encountered in use.

3.4.10.2 The contractor should devise, implement and audit such instructions, to include the following information:

- **a)** intended conditions of use;
- **b)** installation requirements and methods;
- **c)** assembly;
- **d)** adjustment;
- **e)** taking into service;
- **f)** actual usage;
- **g)** maintenance requirements.

Further details of some of these aspects are given in Attachment 7.

3.4.10.3 Reference should also be made to:

- **a)** 16th edition of the IEE wiring regulations (BS 7671);
- **b)** BS EN 61000-5-2, Part 5 Installation and mitigation guidelines, Section 1 - General considerations;
- **c)** BS EN 61000-5-2, Part 5 Installation and mitigation guidelines, Section 2 - Earthing and cabling.

3.4.11 Documentation Submissions

3.4.11.1 Background

The following documentation submissions are essential if the EMC requirements for a compliant system are to be achieved. A brief description of the main submissions is given below.

3.4.11.2 Planning of submissions

3.4.11.2.1 To the maximum extent possible, submissions should be phased so as not to overload the resources of LU's review staff. Presentation of multiple extensive submissions at one time should be grounds for extending the review period and the Contractor will be advised accordingly. Under these conditions extension of the review period should not be grounds for extension to the Contractor's completion date.

3.4.11.2.2 All submissions should comply with the requirements of this document and the contractor should provide all documentation, calculations, design data and submissions necessary to demonstrate compliance with this document.

3.4.11.2.3 It should be noted that additional documentation may be needed if a formal submission through the LU SAP is required. The project engineer should contact the ED before an ITT is issued to determine if such a submission is required and the type of documentation that will be required before acceptance of the system can occur.

3.4.11.3 General

3.4.11.3.1 The documentation requirements of the Quality, Environmental, Safety & Health (QUENSH) conditions will also apply where applicable.

3.4.11.3.2 All submissions should be written in English and submitted to LU for review and approval.

3.4.11.3.3 All test procedures, plans and other required documentation should be submitted for approval at least 60 days prior to testing and all test results should be submitted no later than 30 days after completion of the tests.

3.4.11.3.4 All amendments should be:

a) marked with 'change bars';

b) supplied on paper copy and in WORD 2002 format (on disk).

3.4.12 FTA, Hazard Analysis, FMEA and Instructions for Use.

These submissions may be in a contractor preferred format but this should be agreed at the initial stage of the contract. Contact with the LU SAP and Railtrack SRG or RSAB (as applicable) should be made to confirm any format requirements at an early stage.

3.4.13 EMC Control Plan (See Attachment 3)

This document is fundamental if the system EMC and acceptance from the ED is to be achieved. It must document the overall approach, design procedures and techniques that will be used by the contractors to meet the ED Essential Requirements. This plan should address a number of key issues which are detailed in Attachment 4.

3.4.14 EMC Test Plans (See Attachment 4)

3.4.14.1 This document is fundamental if acceptance is to be achieved with the minimum time and effort.

3.4.14.2 An EMC Test Plan should be prepared for each system or equipment and submitted to LU for review and approval. This plan is required to demonstrate to LU that the system and equipment meet the ED and statutory EMC requirements and the contractor has employed the appropriate expertise and made the required provision for EMC testing.

3.4.14.3 After initial approval by LU, the plan should be amended as required by the contractor during the contract to reflect changes in system design or the identification of additional testing requirements.

3.4.14.4 The test plan should be of sufficient detail to ensure that the tests can be fully reproduced at a later date if required.

3.4.14.5 A detailed EMC Test Plan should be submitted at least 60 days prior to conducting any tests. The plan should address a number of key issues which are detailed in Attachment 4.

3.4.15 EMC Test Report (See Attachment 5)

A detailed EMC Test Report is required so provide evidence that the requirements have been met and should be submitted within thirty days of test completion. The report should address a number of key issues which are detailed in Attachment 6.

3.4.16 Integrated Test Plan (See Attachment 6)

The contractor should submit an integrated test plan for approval within 60 days of award of Contract. This plan should demonstrate that the Contractor has considered all the testing requirements including system integration testing and has made adequate provisions for testing in the overall programme; and to achieve an early mutual understanding between the contractor and LU on the range, depth and other aspects of tests to be conducted. The Test Plan should demonstrate that the Contractor has supplied a complete, safe and operable system and should contain the requirements detailed in Appendix 6.

3.4.17 Declaration of Conformity.

3.4.17.1 The contractor should provide a declaration of conformity when all requirements of the EMC Directive, LU and HMRI have been met.

3.4.17.2 The declaration of conformity may be used by the ED to confirm that the requirements of this document have been satisfied. It should be issued by the Contractor and validated by the LU project engineer to ensure it that it will provide an adequate level of assurance. The document should be in English and contain the following information:

a) description of the system to which it refers;

b) reference to the standard(s) and specification(s) against which conformity is declared;

c) confirmation that the system is safe to operate;

d) the name and address of the responsible person and the contractor;

e) identity of signatories;

f) date of issue;

g) declaration of Conformity with the EMC Directive.

3.4.18 Completion Certificate.

The Contractor should provide a completion certificate to the ED confirming that the installed system meets the ED requirements set out in this document.

4 Responsibilities

Persons designing, specifying, erecting or inspecting electrical installations are responsible for the application of this document.

The Chief Engineer is responsible for auditing compliance with the provisions of this document.

5 Supporting information

5.1 Safety considerations

5.1.1 Although this document is not directly safety related, its overall objective of promoting EMC of installed systems will be of benefit with regard to both safety and reliability, e.g. avoidance of signalling wrongside failures.

5.1.2 This document also addresses means to provide confidence in the EMC status of equipment for submissions to approvals bodies such as HMRI.

6 Informative References

6.1 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 should be followed until new documents have been authorised for use.

Note: References to particular EC 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.

British Standards

Document no.	Title
BS 7671	Requirements for electrical installations. IEE Wiring Regulations. Sixteenth edition
BS EN 1000-2-6	Electromagnetic compatibility (EMC). Environment. Assessment of the emission levels in the power supply of industrial plants as regards low-frequency conducted disturbances
BS EN 1000-2-7	Electromagnetic compatibility (EMC). Environment. Low frequency magnetic fields in various environments
BS EN 1000-3-6	Electromagnetic compatibility (EMC). Limits. Assessment of emission limits for distorting loads in MV and HV power systems. Basic EMC publication
BS EN 1000-3-7	Electromagnetic compatibility (EMC). Limits. Assessment of emission limits for fluctuating loads in MV and HV power systems. Basic EMC publication
BS EN 1000-3-8	Electromagnetic compatibility (EMC). Limits. Guide to signalling on low-voltage electrical installations. Emission levels, frequency bands and electromagnetic disturbance levels
BS EN 50082-2	Electromagnetic compatibility. Generic immunity standard. Industrial environment
BS EN 50121	Railway EMC standards
BS EN 50121-1	Railway applications. Electromagnetic compatibility. Emission and immunity of fixed power supply installations and apparatus
BS EN 50121-2	Railway applications. Electromagnetic compatibility. Emission and immunity of fixed power supply installations and apparatus
BS EN 50121-3	Railway applications. Electromagnetic compatibility. Emission and immunity of fixed power supply installations and apparatus
BS EN 50121-4	Railway applications. Electromagnetic compatibility. Emission and immunity of fixed power supply installations and apparatus
BS EN 50121-5	Railway applications. Electromagnetic compatibility. Emission and immunity of fixed power supply installations and apparatus
BS EN 50155	Railway applications. Electronic equipment used on rolling stock
BS EN 50238	Compatibility Between Rolling Stock and Train Detection Systems
BS EN 61000-3-2	Electromagnetic compatibility (EMC). Limits. Limits for harmonic current emissions (equipment input current ? 16 A per phase
BS EN 61000-3-3	Electromagnetic compatibility (EMC). Limits. Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ? 16 A per phase and not subject to conditional connection

Document no.	Title
BS EN 61000-4-10	Electromagnetic compatibility (EMC). Testing and measurement techniques. Damped oscillatory magnetic field immunity test. Basic EMC publication
BS EN 61000-4-11	Electromagnetic compatibility (EMC). Testing and measurement techniques. Voltage dips, short interruptions and voltage variations immunity tests
BS EN 61000-4-12	Electromagnetic compatibility (EMC). Testing and measurement techniques. Oscillatory waves immunity test. Basic EMC publication
BS EN 61000-4-16	Electromagnetic compatibility (EMC). Testing and measurement techniques. Test for immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz
BS EN 61000-4-9	Electromagnetic compatibility (EMC). Testing and measurement techniques. Pulse magnetic field immunity test. Basic EMC publication
BS EN 61547	Specification for equipment for general lighting purposes. EMC immunity requirements
BS IEC 1000-3-5	Electromagnetic compatibility (EMC). Limits. Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 16 A
BS IEC 61000-2-7	Electromagnetic compatibility (EMC). Environment. Low frequency magnetic fields in various environments

LU company documents

Document no.	Title
D001-ESHM-90-0	
1-193	Maximum levels of interference permitted within SCSE trackside equipment
1-194	Signalling Control - Functional Requirements
1-195	Signalling - Functional Requirements
1-196	Signalling and Signalling Control - Concept and Requirements
1-197	Signalling and Signalling Control - Design and Implementation
1-198	Signalling and Signalling Control - Installation, Testing, Commissioning and Handover
1-199	Signalling and Signalling Control - Operation and Maintenance
1-200	Signalling and Signalling Control - Alterations to Systems
1-201	Signalling and Signalling Control -Approvals

6.2 Abbreviations

The following abbreviations are created:

a) within the engineering function and are listed in 1-622;

b) from published sources.

Abbreviation	Definition	Source
CCTV	Closed Circuit Television	a
CE	symbol denoting compliance with relevant EU Directives	a
ED	Engineering Directorate	a

Abbreviation	Definition	Source
CISPR	Comité International Spécial des Perturbations Radioélectriques	a
CRT	Cathode Ray Tube	a
EEA	European Economic Area	a
EMC	Electromagnetic Compatibility	a
EMI	Electromagnetic Interference	a
EN	European norm	a
FMEA	Failure Modes and Effects Analysis	a
FTA	Fault Tree Analysis	a
HMRI	Her Majesty's Railways Inspectorate	a
ITT	Invitation To Tender	a
ITU	International Telecommunications Union	a
LISN	Line Impedance Stabilisation Network	a
LU	London Underground	a
PA	Public Address (system)	a
REC	Regional Electricity Company	a
RF(I)	Radiofrequency (Interference)	a
rms	root mean square	a
RSAB	Rolling Stock Approvals Board	a
SAP	Safety Approval Panel	a
SRG	Safety Review Group	a
UPS	Uninterruptible Power Supply	a
UTS	Underground Ticketing System	a

6.3 Definitions

The following topic specific definitions are created:

a) within the engineering function and are listed in 1-622;

b) from published sources.

Term	Definition	Source
Contractor	A company, firm, person, supplier, consultant, sub contractor, agent or stockist, providing goods, materials or services. Contractors may be company employees.	A
Project Engineer	Nominated engineer with overall responsibility for delivering the engineering effort in a project	a

6.4 Requirement owner

Paragraph number	Owner
All	EMC Engineer

6.5 Document history

Edition	Date	Notes
R5	August 2007	Standard 5-01018-001 re formatted and re-numbered to G-222, 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

7 Attachments

7.1 Attachment 1 - Requirements for Systems not included in BS EN 50121

Emission Levels for Apparatus

Ports	Frequency Range	Limits	Reference Test Method	Remarks
The equipment enclosure (Radiated emissions)	30-230 MHz 230 - 1000 MHz	40 dBμV/m QP measured at 10m distance 47 dBμV/m QP measured at 10m distance	BS EN 55022	Radiated disturbance, See Note 1. See Note 1.
a.c. and d.c. power ports (Conducted emissions)	0.15 - 0.5 MHz 0.5 - 5 MHz 5 - 30 MHz	79 dBμV QP 66 dBμV AV 73 dBμV QP 60 dBμV AV 73 dBμV QP 60 dBμV AV	BS EN 55022 CISPR 16-1	for a.c. use LISN in CISPR 16-1 See Note 2. for d.c. use LISN in CISPR 16-1 See Note 2.
QP= Quasi Peak Detector, AV=Average Detector				

Immunity Requirements for Apparatus.

The immunity requirements should comply with the following table:

Enclosure Port

Environmental phenomena - Basic standard (including test set-up)	Limits and Test Specification	Performance Criterion	Remarks
Radiated electromagnetic field, BS EN 61000-4-3 ENV 50204	80 - 1000 MHz 10 V/m (rms unmodulated) 80% AM (1 kHz) 900 MHz, 10 V/m pulse modulated, duty cycle 50%, rep. Frequency 200 Hz	A A	None None
Electrostatic discharge BS EN 61000-4-2	6 kV Contact discharge and 8 kV air discharge.	A	None
Power frequency magnetic field, BS EN 61000-4-2	100 A/m d.c. and 50 Hz	B	See Note 3
Damped oscillatory magnetic field, BS EN 61000-4-8	30 A/m	B	See Note 3

Interfacing cable I/O Ports (e.g. data and signalling)

Environmental phenomena - Basic standard (including test set-up)	Limits and Test Specification	Performance Criterion	Remarks
Conducted radio frequency, BS EN 61000-4-6.	0.15 MHz - 80 MHz, 10 V	A	None

Fast transient, BS EN 61000-4-4 (direct injection)	2 kV	A	None
Surge voltage 1,2/50μs BS EN 61000-4-5	2 kV common mode 1 kV diff. Mode 2 kV diff. Mode in unbalanced system	A	None

Earth Port

Environmental phenomena - Basic standard (including test set-up)	Limits and Test Specification	Performance Criterion	Remarks
Conducted radio frequency, BS EN 61000-4-6.	0.15 MHz - 80 MHz, 10 V	A	None
Fast transient, BS EN 61000-4-4 (direct injection)	2 kV	A	None
Surge voltage 1,2/50μs BS EN 61000-4-5	2 kV common mode.	A	None

a.c. and d.c. Power Ports

Environmental phenomena - Basic standard (including test set-up)	Limits and Test Specification	Performance Criterion	Remarks
Conduct radio frequency, EN 61000-4-6.	0.15 MHz - 80 MHz, 10 V	A	None
Fast Transient - EN 61000-4-4 (capacitive clamp)	2 kV	A	None
Surge voltage 1.2 / 50 μs - EN 61000-4-5	2 kV common mode 1 kV diff. Mode 2 kV diff. Mode in unbalanced system	A	None

NOTE 1: Class B emissions are required for systems operating within 10m of a communications receiver.

NOTE 2: Class B emissions are required for systems whose supply is obtained from a REC.

NOTE 3: This test only applies to apparatus containing devices sensitive to magnetic fields (e.g. CRTs, photomultipliers, Hall effect devices) which are installed within 3m of the track or any other significant source of magnetic fields (e.g. power transformer, power cable).

7.2 Attachment 2 - Example of EMC Specification Requirements.

Below is an example of the type of wording that could be used in a contractual document. In some cases the wording may be excessive or inadequate depending on the size and complexity of the system to be purchased. The wording should not be copied verbatim but should be modified to suit the particular system being purchased.

The Essential Requirements

All electrical and electronic equipment manufactured, supplied or installed by "the contractor" shall:

a) Not cause any electromagnetic interference under all normal and failure operating conditions;

b) Operate correctly, without degradation of quality, performance or loss of function within the electromagnetic environment in which it is to operate under all normal operational and failure conditions;

General

The BS EN 50121 series of Railway EMC standards contains many of the tests relevant to the LU System. However, because of the special characteristics of the LU and surrounding environment, additional requirements have been specified (e.g. to address “special cases”, to ensure existing systems remain EMC compliant and to meet various Chief Engineer's requirements) in the ED Standard and Manual of Best Practice to ensure the total threat is considered and mitigated.

The contractor shall review the test requirements detailed in the ED Standard and Manual of Best Practice and liaise with LU to determine the worst case electromagnetic environment in which the system is to function. A clear understanding of the presence of, and electromagnetic emissions from, all potential sources of interference shall be determined by:

a) A review of the 'EMC Standards';

b) Analysis;

c) Direct measurement at representative worst case sites, to be agreed with LU.

All systems, including 'off the shelf' items and cabling, shall comply with the EMC Directive (Ref 89/336/EEC, 92/31/EEC and 93/68/EEC) and the worse case test requirements detailed in the EMC Standards.

The contractor shall show evidence of compliance with the Contract requirements by:

a) Performing the required, worse case, tests detailed in the EMC standards;

b) Affixing CE marks as appropriate;

c) Formal submission, for review and approval, of the EMC Control Plan, Test Plans, Test Reports and any data considered a requirement by LU.

All submissions shall be written in English and submitted to LU for review and approval. Where submissions are derived by translation, these shall be certified to be a true and accurate rendition of the original text.

In any case where conflict arises between these requirements and other related standards or specifications then the more stringent test parameters shall apply.

The System shall comply with all the requirements of the contract and will not be interpreted as an “excluded installation” as defined in Statutory Instrument 1992 No. 2372.

The contractor shall liaise with LU at the earliest opportunity to define and resolve any conflict which may arise either within the electromagnetic compatibility requirements or with any other engineering requirements detailed in the Contract.

The contractor shall demonstrate and supply any data requested by LU (e.g. previous test results, test reports, details of hardware, software or firmware changes between tested and supplied equipment) to verify that any equipment supplied as 'off the shelf' will also meet the requirements detailed in the Contract. The contractor shall carry out any additional work required to satisfy these requirements when previous testing or the content of documentation supplied is considered by LU to be inadequate.

The system shall be tested in the worse case conditions for emissions and immunity. Where doors, panels and covers are removable during site maintenance, these should be removed or opened during the appropriate immunity tests.

EMC system integration tests shall also be carried out to demonstrate that the system is electromagnetically compatible with all existing systems.

LU shall be invited to all Contractor design reviews and formal or pre-compliance tests. A period of notice shall be agreed with the Contract Manager or his representative for all such tests.

The contractor shall demonstrate that:

The System can comply with the 'Essential Requirements' and co-exist without causing interference to any existing system(s).

The contractor shall inform the Contract Manager at the earliest opportunity in the event that any analysis or testing demonstrates a potential conflict which may arise within the EMC requirements.

The contractor shall demonstrate that the System complies with all relevant EMC requirements by one of the routes to compliance detailed in Statutory Instrument 1992 No. 2372 and any subsequent amendments. The proposed route shall be approved by LU.

Whilst it is necessary to satisfy the essential legal requirements of the EMC Directive it is also required that EMC testing is selected to suit the particular equipment environment and to demonstrate that the equipment is fit for purpose and meets the requirements of the EMC Standards. It is not sufficient to select equipment solely on the basis of the 'CE' mark. The contractor shall also demonstrate and inform LU of the following:

a) The tests that have been performed;

b) The test limits that have been selected;

c) The acceptance criteria applied;

d) That all the tests are sufficient in terms of applied level, frequency range and equipment operation to meet LU requirements.

The choice of acceptance criteria for EMC shall depend on the nature and intended function of the equipment and the impact on overall system considerations such as reliability, safety and performance.

The contractor shall recommend which criterion is the most appropriate in each case, to be endorsed by LU. Criterion A shall apply unless otherwise stated.

EMC Review Meeting

The contractor shall attend and support these meetings as and when requested by LU. The meeting shall be held at least bi-monthly to review progress, test requirements and areas of concern. An EMC representative from the contractor shall attend, together with any other LU representatives required. The exact scope will be determined at the initial meeting.

EMC Environment

The System shall meet the 'Essential Requirements', in all modes of operation, including failure modes, in close vicinity to a wide range of existing and modern systems, e.g:

a) LU 600V dc traction power supplies;

b) 750V DC 3rd rail mainline electrification;

c) High voltage mainline overhead electrification;

d) High voltage National Grid pylons;

e) Any other high voltage installations or transmission systems;

f) Railtrack 25 kV overhead main line electrification;

g) All types of LU railway signalling systems;

h) Railtrack signalling systems;

j) Other signalling systems;

k) Rolling Stock used in or having an interface to LU operations;

l) LU substations;

m) LU Radio System and station communications systems;

n) LU Telephone Exchanges;

o) Public Telecommunications Operator equipment;

p) Railtrack station communication systems;

q) Public broadcasting services;

r) Customer goods and appliances;

s) Rolling stock electronics;

t) Adjacent Railtrack owned equipment;

u) Docklands Light Railway equipment;

v) Public and private communications operators.

Induced Voltage Study

The contractor shall undertake a compatibility study to show that the levels of induced voltage on cables will not exceed the limits stipulated below. All equipment forming part of the system to be realised under this Contract shall be immune to the effects of characteristic induction fields (which may contain significant amounts of energy) surrounding any power electronic equipment.

All equipment and cables shall be adequately protected from the effects of the characteristic inducing field generated by the Rolling Stock and traction power supply. Cable sheaths shall be earthed in such a manner as to provide maximum protection from any inducing field affecting the safety or reliability of the system. The earthing system shall prevent any longitudinal voltage, which could cause a hazard to personnel or adversely affect the operation of equipment connected to the cables, from exceeding the values:

a) Continuous 25 V rms;

b) Non-continuous (fault conditions) 430 V rms.

In addition, the system shall not give rise to a psophometrically weighted transverse noise voltage in excess of 1 mV.

The contractor shall ensure that all equipment is immune to adverse effects from adjacent systems such as but not restricted to:

a) 750V DC 3rd rail mainline electrification;

b) High voltage mainline overhead electrification;

c) High voltage National Grid pylons and cables;

d) High voltage power supplies;

e) Any other high voltage installations or transmission systems.

7.3 Attachment 3 - EMC Control Plan Requirements

As a minimum, the Control Plan should contain the following:

a) Organisational responsibilities with respect to EMC should be provided including the name and contact details for a single point of contact. This should include information as to responsible EMC design, analysis and test engineering contacts, and names of individuals responsible for support of design reviews and EMC documentation. A schedule of EMC events or milestones should be included, along with a detailing of known contractual requirements for the systems, and a summary of EMC requirements passed to subcontractors by the contractor. All applicable EMC documentation should be identified in the Plan, together with all EMC specifications (and versions thereof) which are to be used in design;

b) Operational parameters of the system and its intended installation should be adequately and concisely described. Identify, for example, which parts of the system are contained within an equipment room, which are external, estimated separation distances, and mounting considerations;

c) A summary of mechanical design as related to EMC should be provided in the Plan. Materials should be described, as well as procedures and methods to be used for purposes of attenuating electromagnetic emissions and reducing susceptibilities of equipment to the specified electromagnetic threats. A description should be given of internal shielding and filtering methods used to achieve compliance. Mechanical drawings may be used to identify the locations and physical characteristics of possible apertures, electrical connectors and panel mounted components, and design details of RFI gaskets (if used) should be given;

d) Filter characteristics and component values of powerline filters should be provided, if used. If filter pins are to be employed in design, the attenuation and peak rating characteristics should be included. A description of construction materials employed in design should be given. Bonding surfaces should be identified, together with details of any surface treatment used for achieving compliance with applicable ED earthing and bonding specifications;

e) The schedule for documentation submissions and audit of the agreed approval process;

f) All wiring and cable design required to minimise emissions and susceptibilities should be described by diagram or other means. Choice of wire type and wire treatment (e.g. twisted, twisted-pair, shielded) and wire routing methodology should be provided. Wire separations or special treatment of wires identified as being susceptible to EMI or capable of being a source of interference, and isolation or other method(s) used to achieve compliance, should be given. Technical criteria should be provided to justify usage of cable shields or filter pins;

g) A description of grounding methods should be given. A grounding diagram may be used to show methods by which overall grounding, treatment of power and signal returns, and power distribution within or between individual system units is achieved;

h) The main sources of interference and susceptibility threats should be identified. A summary of clock frequencies, data rates, and frequencies of RF carriers utilised in design should be provided as applicable;

j) The contractor should identify areas in design in which EMC problems are either known or anticipated. Both a description of procedures to be used for analyses and a summary of proposed solutions to interference problems should be given;

k) The contractor should provide a method by which this Control Plan may be upgraded throughout the development program. This plan should accurately reflect all current EMC requirements levied upon contractor-provided system;

l) Evidence of contractors satisfactory capability in dealing with EMC matters on previous projects;

m) Any differences between 'off the shelf' equipment, the ED requirements, and how these gaps are to be addressed, How 'special cases' will be identified and resolved;

n) The proposed route to demonstrate compliance with the EMC Directive;

o) Details of the installation guidelines and cable classification and segregation system used to achieve system EMC;

p) An EMC management structure which identifies the key EMC specialists and their relationship to other disciplines within the Project. The relationship with external companies and with LU should be identified. This is most effectively presented in the form of a diagram, with brief notes of the role and the relationships of key individuals. Emphasis is required on the cross-discipline and independent nature of the EMC specialists, showing that they can effectively influence the design when EMC aspects are at variance with other constraints;

q) Details of the contractor's management of design change control, audit and failure recording and review;

r) Maintenance requirements needed to maintain the system EMC after installation.

7.4 Attachment 4 - Test Plan Requirements.

As a minimum, the Test Plan should contain the following:

a) Comprehensive details (e.g. test levels, limits and ranges) of the tests to be performed and on exactly which wires associated with equipment under test. Any wires not tested must be approved by LU;

b) Description of all equipment operating modes. Any mode not evaluated during test(s) must be approved by LU;

c) Methods and locations for monitoring equipment performance and quantitative criteria for determining the immunity pass/fail criteria;

d) Specific and detailed electrical test set-up diagrams which clearly show the routing of power wiring, interconnect wiring, ground wires, circuit loads, wiring configuration (such as twisted, shielded, shield grounds, wire lengths) and equipment under test identification;

e) Specific implementation of each general test procedure to the equipment under test. Copies of the generalised test set-ups from the standards are not acceptable for the specific equipment under test. The level of detail required in the test procedure should allow an experienced EMC engineer to conduct the tests with little knowledge of the particular equipment under test.

7.5 Attachment 5 - Test Report Requirements

All test reports should be submitted for review and approval. The report should contain, as a minimum, the following information:

a) A summary of the test results including reference to any failures and tests not performed;

b) A list of individual tests performed, test results and emission profiles. Any changes to the test procedure, layout or test parameters, previously authorised, should be documented;

c) Nomenclature and serial numbers of test equipment used should be included, together with most recent calibration dates of interference measurement equipment;

d) A diagram of the test set-up should be given which includes the equipment under test, associated support equipment, loads and test equipment used. In addition, wire and cable layouts, lengths and separations should be provided. Photographs may be used to supplement the set-up description;

e) Equipment identification, including complete nomenclature, manufacturer, part numbers, and serial numbers should be given, together with a description of the equipment function, its intended use and installation (if known).

7.6 Attachment 6 - Integrated Test Plan

The Integrated Test Plan should be submitted for review and approval and will contain, as a minimum, the following information:

a) A flow diagram indicating the logical sequence of tests starting with the initial equipment test and inspections and concluding with system demonstration tests;

b) A list of test plans to be submitted, a preliminary submission programme and a brief description of each factory and site test;

c) An outline and format of the procedures and test data sheets for each type of test;

d) Requirements for LU personnel or equipment;

e) Requirements and recommendations for witnessing by LU personnel;

f) A description of the Contractor's factory and field test organisations;

g) A description of the flow of quality assurance and test data;

h) How the requirements will be managed and progress will be reported;

The Contractor should submit a 30 day look ahead programme detailing all the testing activities proposed for the period covered. The first programme should be submitted 30 days prior to the first test and a revised programme should be submitted every 14 days thereafter. For each test, this should include the planned start and finish dates and the names of the staff members responsible for conducting the test.

7.7 Attachment 7 - Additional Information on 'Instructions for Use of the system'

Background

Installation technique is very important if the system EMC is to be achieved and this must be devised and approved at an early stage of any project (not just before the installation process is scheduled to start). Any system or equipment, which has met a rigid set of type test requirements can easily fail to meet the requirements if it has been incorrectly installed or maintained. For example, if a sensitive cable is routed adjacent a power cable or if a VDU is located near a power transformer, problems are likely to occur.

The following documents contain many expects of good installation technique that will promote EMC of the system.

a) 16th edition of the IEE wiring regulations (BS 7671);

b) BS EN 61000-5-2, Part 5 Installation and mitigation guidelines, Section 1 - General considerations;

c) BS EN 61000-5-2, Part 5 Installation and mitigation guidelines, Section 2 - Earthing and cabling.

The paragraphs below list a number of issues which are fundamental if the EMC of the system is to be achieved. Some of these items are extensions of the installation requirements set out in the IEE wiring regulations (BS 7671), BS EN 61000-5-2 and other related system regulations. In the event of any conflict between this document and the above, safety must be the primary concern and any conflict must be reported to the ED. The requirements of the IEE wiring regulations and other related system regulations (e.g. separation distances for fire alarm wiring, ED signalling requirements) must take precedence over these requirements.

Cable Rules

The main source of radiation from, or coupling mechanism into, any system is caused by external cabling which, due to their lengths, provide an efficient mechanism to cause EMC problems. The coupling of interference between cables can be reduced significantly by observing certain rules, during installation, which will reduce the inductive and capacitive coupling between cables.

In general, these rules should be devised and specified for a particular system to take account of any special requirements or constraints. In formulating these rules the cables are classified according to whether they are likely to radiate interference, or are connected to susceptible equipment, and also by the levels of interference or signal which they are carrying. The rules specify the required segregation distances between cables of the various classes.

The proposed set of rules should be validated by analysis and approved before they are implemented.

The separation of sensitive cabling (e.g. signalling and communications) from the many potential sources of EMI is essential if EMC is to be achieved. If the separation distances cannot be achieved for practical reasons, additional protection may be required (e.g. trunking or re-routing). In addition, all cable 'cross over points' should be at right angles and parallel lengths should be minimised wherever possible.

Cable Classification

Various methods of classifying cables can be employed, depending on the degree of complexity which is required for a particular type of system. The following example is a fairly simple classification and is intended to give a general ideal of the concept. It must not be must not be used in any system specification. The exact separation distances must be validated by analysis and on site measurements.

The minimum separation distances required by the ITU, Fire regulations and the IEE wiring regulations must also be considered when such a system is devised.

In practice, it may be difficult, and in some instances impossible, to maintain the separation distances below over the entire cable runs (e.g. at cable entries into voids orcabinets). However, for all parallel cable runs, every attempt should be made to achieve the required segregation.

The cables are divided into three main categories:

Radiators, Susceptors and General.

In each category cables are sub-divided according to the types and levels of interference and signal being carried.

Radiators:

Category - R1

a) Power cables up to 80 A < 415V;

b) Transmitter output cables (systems operating below 100 kHz);

c) Transceiver cables.

Category - R2

Power cables (50 Hz) more than 80 A > 415V.

Susceptors:

Category - S1

Receiver input cables, systems operating below 100 kHz, signals less than 100 µV.

Category - S2

Receiver input cables, systems operating below 100 kHz, signals in the range 10 µV to 100 mV.

Category - S3

a) Cables that carry low level voltage and current signals (e.g. Signalling Cabling);

b) Coaxial cables to receivers and video systems operating above 100 kHz.

Category - General

a) Coaxial cables to transmitters operating above 100 kHz;

b) Cables carrying low frequency signals above 0.1 V.

Segregation Distances

For example, the classification system given above could require the following minimum separation distances:

S1 to	G	100 mm *Example only*
	R1	100 mm *Example only*
or	R2	150 mm *Example only*
S2 to	G	75 mm*Example only*
or	R1	100 mm *Example only*
S2 to	R2	100 mm (increase by 75 mm per 50 A above 160 A) *Example only*

S3	R2	200 mm (increase by 75 mm per 50 A above 160 A) *Example only*
G to	R1	75 mm *Example only*
or	R2	100 mm (increase by 75 mm per 50 A above 160 A) *Example only*

The use of screened cable, metal trunking and conduits will also reduce the cable emissions and provide adequate protection for system cabling. The above separations could also be reduced.

System and Equipment Separation

The placement of any equipment into an operational railway must be carefully considered before the installation process begins. This should ensure that any EMC problems, which could be caused by both intentional (e.g. radio base stations) and unintentional equipment emissions, are avoided. This issue is particularly important when a diverse range of systems are co-located (e.g. station platform area) or when a new system is proposed to be installed adjacent to a system of unknown EMC status.

Equipment considered potentially sensitive (e.g. communication receivers, VDUs, low level signalling systems and components) should not be co-located close to potentially emissive equipment (e.g. power transformers and cables, electric motors). Additional analysis and protection measures may be needed where this cannot be achieved, which should be identified and resolved at the initial stage of a project.

Earthing

The availability of a good earthing system, installation methodology and the practice of ensuring that equipment enclosures and cable screens are earthed by a low impedance bond is essential if the system EMC is to be achieved.

One of the main objectives for EMC earthing is:

a) Ensure that the 'earth' at each of the system equipment is at the same potential to minimise coupling between systems and equipment that share the same earth;

b) Divert unwanted interference currents from cable screens, equipment filters and transient protection devices back to earth and not to other systems.

The ideal EMC earthing would be a combination of a single point system for low frequency systems and a multi-point system, where voltage differentials must be minimised, for high frequency systems.

Reference should be made to:

LU Earthing Philosophy, SE 858.

BS 7671 - 16th edition of the IEE wiring regulations.

BS 7430 - Earthing.

BS EN 61000-5-2, Part 5 Installation and mitigation guidelines, Section 1 - General considerations.

BS EN 61000-5-2, Part 5 Installation and mitigation guidelines, Section 2 - Earthing and cabling.

The chosen earthing must also consider events under failure conditions and safety must be the over riding concern.

Bonding

Bonding is the establishment of a low impedance connection between two metal surfaces.

The following list is considered good bonding practice:

a) Use the same metal or metals close together in the electrochemical series;

b) Bonds should be correctly tightened and coated to prevent moisture ingress;

c) Bonds should be short, wide and flat to minimise impedance (braids should be avoided where possible).

Maintenance

The system or equipment maintenance schedule must include any design aspects that have been included to achieve EMC. These will include:

a) Some RFI door gaskets will need to be replaced because they will not remain effective after a certain number of door compression cycles;

b) Bonding and earthing connections will need periodic re-testing and tightening.

Corrosion

Corrosion can greatly reduce the effectiveness of any earthing or bonding system by increasing the impedance of the earth or bond. This will greatly reduce the advantages of a good earth detailed above and reduce the effectiveness of any EMC design measures.

Corrosion can occur when dissimilar metals are connected together or when inappropriate materials have been used and are affected by external conditions such as dampness, salt mist or rain. Corrosion will always occur but its effect on the system EMC performance must be minimised by:

a) Selection of appropriate materials at the initial design stage for the operational environment;

b) Ensuring any dc leakage currents are negligible;

c) Good installation practice that will ensure the bond is correctly tightened;

d) Maintenance of the earthing and bonding systems;

e) Ensuring the equipment location is not damp where possible.

7.8 Attachment 8 - EMC Installation Check Sheet Example.

This guidance note is intended to provide basic instructions, to competent site personnel, so that the correct approach and periodic review is adopted which should ensure that the 'Installation' will be, and will remain, EMC without the need to refer to a large number of regulations or specifications. It is not intended to replace the requirements of any site drawing, LU or IEE regulations, codes of practice, site specifications, site tests and inspections or the request for advise from the appropriate engineers.

More importantly, this note will establish the need to report all appropriate site changes and problems to the appropriate engineer for review and further action as appropriate.

If the answer to any of the questions below is unclear, advice must be sought from the engineer.

1. All installed equipments are 'CE' marked.

2. All installed equipments have been 'Type' approved.

3. All installation drawings have been approved.

4. All metalwork is earthed and bonded in accordance with the contract and the project code of practice.

5. The installation is periodically inspected and tested.

6. Where appropriate, the electrical installation completion certificate is satisfactorily completed.

7. The equipment installation is in accordance with the IEE regulations and the approved drawings.

8. All re-routing of cabling and trunking is reported to the engineer for review.

9. All approved changes have also been included in the approved site specifications and drawing.

10. Cable screens are fitted in accordance with the approved drawings and are mechanically sound.

11. There is no evidence of corrosion of the electrical system.

12. All bonding straps are as short as possible but are not over-stretched.

13. All bonding straps, connectors, connector backshells have been fitted and tightened in accordance with the approved drawings.

14. Ensure that parallel cable runs have been kept to a minimum.

15. Cable separation distances have been maintained and validated.

16. All changes that could have affected any of the above have been reported.

17. All trunking, conduit and cable trays are securely fixed and protected against damp or corrosion.

18. All trunking, conduit and cable trays are earthed and all joints are mechanically sound.

19. The number of cables fitted in or on trunking, conduit and cable trays is in accordance with the approved drawings and not excessive.

20. The contractor cable classification system is being used.

21. The project earthing, bonding, corrosion prevention and lightning protection requirements are enforced.

22. Any re-siting of trunking, equipment, cabling and antennas etc. must be reported to the engineer.

23. Installed equipments are adequately protected from mechanical damage, water, oil, solvent ingress, misuse and the possible adverse effects of any electromagnetic sources (e.g. electrostatic static discharge, ESD, radio transmitters, welding equipment).

24. During commissioning all observed interference and malfunctions (e.g. disruption of VDUs) are reported and remedied.

25. Electrostatic device handling precautions (e.g. use of earthed discharge straps) are enforced if electronic modules are installed or removed for any reason.

26. All damaged equipments, particularly cabinet doors etc, are reported and repaired.

7.9 Attachment 9 - The EMC Directive

The main objective of the EMC Directive is to guarantee the free movement of apparatus and to create an acceptable electromagnetic environment in the EEA territory. In order to achieve it, a harmonised and acceptable level of protection is requested in the Directive, based on Article 100a of the Union Treaty, leading to full harmonisation in the EEA.

The level of protection requested is further specified in the EMC Directive by protection aims in the field of electromagnetic compatibility. The main goals are:

To ensure that the electromagnetic disturbances produced by electrical and electronic apparatus do not affect the correct functioning of other apparatus according to the definition of Article 1.1 of the EMC Directive, as well as radio and telecommunications networks, related equipment and electricity distribution networks;

To ensure that equipments have an adequate level of intrinsic immunity to electromagnetic disturbances to enable them to operate as intended;

The system should meet the EMC directive by being tested in accordance with the applicable BS EN 50121 series of standards;

To achieve these objectives, the EMC Directive lays down protection requirements and procedures under which the manufacturer may himself assess his apparatus against these requirements or may have it assessed by third parties. Obviously, the goal of the protection requirement is not to guarantee absolute protection of the above apparatus (e.g. zero emission level or total immunity of the apparatus). These requirements accommodate both physical facts and practical reasons. To ensure that this process remains open to future technical developments, the EMC Directive only describes protection requirements along general lines;

When compliant with the provisions of the EMC Directive, electrical and electronic apparatus may be placed on the market in the EEA territory, freely moved and operated as designed and intended in the expected electromagnetic environment.

Limitations

It is recognised that the EMC Directive has limitations and if it was the only specified EMC requirement, unacceptable problems, particularly for low frequency systems, could occur. Such gaps have been generally addressed in this document and the new ED EMC framework standard. The Project Engineer must always require that the proposed system can operate safely and satisfactorily under both normal and credible fault conditions.

The main limitations of the Directive are considered to be:

a) Safety is not addressed specifically;

b) The threat to the most sensitive railway systems are not directly addressed (e.g. track circuits and systems that operate below 9 kHz);

c) Compliance with the Directive can be met solely by analysis;

d) Special cases, which are unique to LU, are not addressed (e.g. the large usage of mobile communications equipment in close proximity to other systems);

e) A 'CE' marked equipment can give a misleading impression on the equipment suitability for use in a railway EMC environment. The project engineer should ensure any 'CE' marking is applicable to a railway environment and not to a less severe one (e.g. domestic);

f) Its implementation is open to wide interpretation which can result in insufficient testing and analysis;

g) The purchase and integration of equipment, based solely upon demonstration of the 'CE' mark, is unacceptable. The individual tests, frequency ranges, test limits and acceptance criteria must be known and be compatible with the ED requirements.