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TRAIN B28

Preliminary Design of EMI-EMC Control Plan

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1. Introduction

The scope of this document is to provide a preliminary technical description of EMI EMC Control Plan and Vehicle Earthing Concept proposed for High-Speed Trains (Chair car of 8-Car formation designed to operate at 249 kmph and test speed of 280 kmph for Train B28 project.

2. Trainset Configuration

The scope is for 8-Chair car High Speed Trainset (also referred as a rake).

Train/Rake configuration: 8 Cars – 2 basic units, each unit consisting of 4 Cars

The tentative configuration of train formation is as follows.

For 8 car formation –

* DTC1 + MC1 + TC + MC2 + MC1 + TC. Ex+ MC2 + DTC2 *

DTC1/DTC2 - Driving Trailer Car,

MC1/MC2 - Motor Car,

TC - Trailer Car with PRM seat,

TC2.Ex - Trailer Car (Executive Car) with PRM

“* “ - Automatic Coupler

“+ “ - Semi-permanent Coupler

3. Abbreviations

The following abbreviations shall be used as applicable:

S.NO	Abbreviation	Full form
1	CDR	Concept Design
2	PDR	Preliminary Design
3	DDR	Detail/Final Design

Table 1: Abbreviations

Further abbreviations are as mentioned in the attached document- **EMI EMC Plan Document for MAE676- High Speed Trainset (B28) (Doc. No. MAE676/EMI-EMC, CD- 3796, Rev.01) –**

1.3 List of Abbreviations used.

4. Applicable Standards/Norms/Code

Applicable Standards and the summary of applicable standards are as mentioned in the attached document- **EMI EMC Plan Document for MAE676- High Speed Trainset (B28) (Doc. No. MAE676/EMI-EMC, CD- 3796, Rev.01) -1.4. Applicable Documents & 7. Summary**

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of Applicable Standards

5. Reference Documents

Table 2: Reference Documents

Sl. No	Title	Doc. Id.	Doc. No.	Remarks
1.	“SPECIFICATIONS AND STANDARDS FOR DEVELOPMENT OF NEW GENERATION ENERGY EFFICIENT TRAIN WITH DISTRIBUTED POWER SYSTEM (LIGHT WEIGHT STAINLESS STEEL BODIES CARS)” and its subsequent Statement of Deviations accepted by ICF/NHSRCL	-	ICF/MD/SPEC/447	-
2.	Test Specification of EMC and EMI	B28/VR.09.00.00/D/B017/--	FPIIC/TD/380	DDR

6. Technical Description

The technical description of EMC Control plan and Vehicle Earthing Concept details are in the attachment-1 of this document - **EMI EMC Plan Document for MAE676- High Speed Trainset (B28) (Doc. No. MAE676/EMI-EMC, CD- 3796, Rev.01)**

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7. Attachments

Table 3: Attachments

Sl. No	Description	Doc / Dwg No.	Rev No.
1.	EMI EMC Plan Document for MAE676-High Speed Trainset (B28)	MAE676/EMI-EMC, CD- 3796	01
2.	Reply sheet to NHSRCL's Feedback on – EMC Control plan and Vehicle Earthing Concept (FPIIC/TD/232, Rev.00)	--	--
3.	Reply sheet to DB's Feedback on – EMI-EMC Control Plan and Vehicle Earthing Concept (FPIIC/TD/232, Rev.00)	--	--

ATTACHMENT – 1

EMI EMC Plan Document for MAE676- High Speed Trainset (B28)

- MAE676/EMI-EMC, CD – 3796, Rev.01

EMI EMC Plan Document for MAE676 - High Speed Trainset(B28)

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		Rev. 1		

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1	25-10-2025	Section, Rev 0 Approved. Section 1.1, 1.2, 1.4.2, 2.1.3, 2.2, 2.2.3, 4, 6.1, 6.2.1, 6.3.7, 6.6.1, 7.2.3, 7.2.5, 7.3.1.1, 7.3.2.2, 7.3.2.3, 7.3.2.4 modified. Section 11, separate document with earthing plan made	Satyanarayanareddy. K	Vinay Namireddy / Pramod Kumar D	Ranjeet Singh

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1 Introduction to EMC

This document describes the measures to be taken during the design of the high-speed trainset, including various electronic systems, control panels, power equipment, and switchgear, to ensure compliance with Electromagnetic Compatibility (EMC) requirements.

Modern trains incorporate a wide range of onboard electrical and electronic equipment, and the interaction among these systems within the complex railway environment can be challenging. Therefore, effective EMC management is essential to ensure the reliable and safe operation of trains. All newly introduced rolling stock must be electromagnetically compatible with existing railway infrastructure, as well as with systems operated by neighboring railways.

An additional challenge lies in managing potential interactions between the train and external environmental factors, including passengers' personal electronic devices. This extends to the manufacturer's responsibility to safeguard passengers and staff from hazards caused by excessive electromagnetic fields.

1.1 Objective

Electromagnetic Compatibility (EMC) refers to the ability of an electrical or electronic system to function satisfactorily within its electromagnetic environment without generating or being affected by unacceptable electromagnetic disturbances. Also system is designed system designed is immune to any EMC related noises from any external environment.

To meet EMC requirements, it is essential to consider all train-borne electrical and electronic equipment, as well as relevant infrastructure and external facilities that interact with the railway system.

This EMC Plan defines both vehicle-level and equipment-level strategies to ensure that Electromagnetic Interference (EMI) is effectively mitigated. The primary objective is to ensure that EMI does not compromise vehicle performance and that the trainset fully complies with all applicable EMC standards and regulations.

During the engineering phase, EMC-related activities are categorized into three main areas:

1. **Internal System Compatibility** : Ensuring electromagnetic compatibility among all electrical and electronic equipment and systems installed within the vehicle.
2. **Infrastructure Interface Compatibility** : Ensuring that the trainset is electromagnetically compatible with external railway infrastructure, including signaling and control systems, traction power supply, and depot-based equipment.
3. **Human and Property Interface Compatibility** : Ensuring that the vehicle's electrical and electronic systems do not adversely affect passengers, staff, or their personal belongings. This includes compatibility with cardiac pacemakers, implanted medical devices, wireless technologies, mobile phones, and portable electronic devices.

1.2 Scope

To clearly define the overall responsibility for Electromagnetic Compatibility (EMC), equipment is categorized into two groups:

1. **Supplied Equipment**: This includes all equipment provided by Medha & BEML, including systems sourced from other vendors, such as the master controller, switchgear, cables and similar components.

2. **Foreign Equipment:** This includes systems not supplied by Medha but which contribute to the overall EMC environment. Examples include signaling systems, train radio, wayside equipment, and passengers' personal electronic devices such as pacemakers, entertainment systems, and personal computers.

For the first category, Medha will ensure that its supplied equipment does not emit electromagnetic interference beyond the limits specified in applicable EMC standards. Medha will also ensure that this equipment functions reliably in electromagnetic environments where interference levels are within those specified limits.

For the second category, Medha will ensure that electromagnetic emissions from its supplied equipment do not interfere with the operation of foreign equipment, as long as the operational limits of such systems are known. Furthermore, Medha's equipment will be designed to meet EMC requirements based on the known characteristics of the railway environment. However, Medha will not be responsible for the performance or compatibility of foreign equipment, nor for general conducted or radiated emissions already present in the external railway environment.

Scope also include:

- a) Defining design rule of EMC- Explained in section 2
- b) Analysis of EMI impact- Explained in section 6
- c) Environmental EMC- Explained in section 6.4
- d) EMC control and Test plan- Explained in section 4, 5, 6, 7 & 8
- e) Submission of document related to EMC

This document defines the EMI/EMC Plan intended to ensure the proper functioning of all electrical and electronic systems within the railway operating environment.

This design is developed in accordance with ICF Specification No.: ICF MD SPEC-447, Issue Status-01, Rev-00, Date: 03-02-2025 – Specification for Standard Gauge High-Speed Trainset.

1.3 List of Abbreviations used

Acronym	Description
AC	Alternating Current
CC	Car Controller
CCU	Central control Unit
CCTV	Closed-Circuit Television
CHM	Crash Hardened Memory
CRW	Cab Rear Wall
DC	Direct Current
DDU	Driver Display Unit
DTC	Driving Trailer coach
ECC	Electrical Control Cabinet

Acronym	Description
ECN	Ethernet Consist Network
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
EP	Electro Pneumatic
ESD	Electro Static Discharge
ETBU	Emergency Talk Back Unit
EUT	Equipment Under Test
FACP	Fire Alarm Control Panel
FDS	Fire Detection System
IFTCU	Infotainment Control Unit
IGBT	Insulated Gate Bipolar Transistor
LIC	Line Inverter Computer
LH DU	Linear Heat Detection Unit
MAR	Media access Router
MCB	Miniature Circuit Breaker
MC	Motor coach
MCU	Main Control Unit
MPCB	Motor Protection Circuit Breaker
MS	Mild Steel
NVR	Network Video Recorder
PCU	Passenger comfort Control Unit
PIS	Passenger Information System
SDBU	Side Destination Board Unit
SMPS	Switch Mode Power Supply
TC	Trailer Coach
TCAS	Train Collision Avoidance System
TCU	Traction Converter Unit
TFT	Thin Film Transistor
TIC	Traction Inverter Computer

Table 1: List of abbreviations

1.4 Applicable Documents

1.4.1 Indian Railway Standards:

- i) ICF Specification No.: ICF MD SPEC-447, ISSUE STATUS-01,REV-00,DATE-03-02-2025: SPECIFICATION FOR STANDARD GAUGE HIGH SPEED TRAINSET

1.4.2 Other Standards

Standard	Description
EN 50121-1	Railway applications: Electromagnetic compatibility Part 1, General
EN 50121-2	Railway applications: Electromagnetic compatibility Part 2, Emissions of the whole railway system to the outside world
EN 50121-3-1	Railway applications – Electro-magnetic compatibility – Part 3-1: Rolling stock – Train and complete vehicle
EN 50121-3-2/ IEC 62236-3-2	Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock - Apparatus
EN 61000-4-2	Electromagnetic compatibility (EMC) Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test
EN 61000-4-3	Electromagnetic compatibility (EMC) Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test
EN 61000-4-4	Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test (2011)
EN 61000-4-5	Part 4-4: Testing and measurement techniques - Surge immunity test
EN 61000-4-6	Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields (2009)
EN 61000-4-8	Part 4-4: Testing and measurement techniques – Power frequency magnetic field immunity test
EN 61000-4-11	Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests (2005)
EN 61000-6-2	Electromagnetic compatibility (EMC) Part 6-2: Generic standards - Immunity for industrial environments (2006)
EN55011/ CISPR 11	Industrial, scientific and medical equipment- Radio frequency disturbance characteristic- Limits and method of measurements
EN 50238-2	Compatibility between rolling stock and train detection systems - Part 2: Compatibility with track circuits
EN 50238-3	Compatibility between rolling stock and train detection systems - Part 3: Compatibility with axle counters (2011)
IEC 60034-1	Rotating electrical machines –Part 1: Rating and performance
IEC 60077	Rules for electric traction equipment
IEC 60077-1	General service conditions and general rules for electric equipment for rolling stock (2002)
IEC 60310	Traction transformers and inductors

Standard	Description
IEC 60349-2	Electric traction; rotating electrical machines for rail and road vehicles; part 2: electronic converter fed alternating current motors
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 60571	Electronic equipment used on rail vehicles
IEC 61133	Electric traction; rolling stock; test methods for electric and thermal/electric rolling stock on completion of construction and before entry into service
IEC 61373	Railway applications - Rolling stock equipment - Shock and vibration tests
IEC 61375-1	Electric railway equipment - Train bus - Part 1: Train communication network
IEC 61377	Electric traction – Rolling stock – Combined testing of inverter-fed alternating current motors and their control
IEC62427	Railway application-Compatibility between rolling stock and train detection system
EN50500	Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure
EN50343	Railway applications – rolling stock – rules for installation of cabling
EN50122-1	Railway applications – fixed installations -electrical safety, earthing and the return circuit -part 1: protective provisions against electric shock
IEC/EN61000-1-1	Electromagnetic compatibility (EMC) - Part 1: General - Section 1: Application and interpretation of fundamental definitions and terms
IEC 61000-5-2	Installation and mitigation guidelines - Earthing and cabling
EN 50153	Railway applications. Rolling stock. Protective provisions relating to electrical hazards

Table 2: Applicable standards

2 EMC Control Process

The EMC Control Process is a structured methodology designed to ensure that Electromagnetic Compatibility (EMC) requirements are met throughout the design, development, testing, verification, and operational phases of a railway vehicle.

This process demonstrates that the vehicle, as designed, built, operated, and maintained, can withstand all identified electromagnetic hazards under defined normal operating conditions. It also ensures that the vehicle does not emit harmful levels of electromagnetic interference (EMI).

By adhering to this process, compliance with applicable EMC standards and requirements for rolling stock is validated. It confirms that the rolling stock equipment has been engineered and integrated in a manner that is consistent with established electromagnetic performance criteria.

Furthermore, the EMC Control Process ensures that critical electromagnetic interfaces particularly those between onboard systems and trackside signaling and communication equipment are effectively managed. Using a combination of estimation, calculation, and simulation techniques, the

risk of functional failure due to EMC-related issues is systematically assessed and reduced to a level that is As Low As Reasonably Practicable (ALARP).

This EMC Plan is structured into the following three main phases:

- Analysis Phase
- Synthesis Phase
- Validation Phase

2.1 Analysis Phase

In this phase, all potential sources of Electromagnetic Interference (EMI) and all susceptible equipment both internal and external to the vehicle are identified.

The purpose of this phase is to assess the electromagnetic environment and define EMC risks early in the design cycle. It involves the systematic collection of technical and environmental data necessary to understand the EMC interactions within and around the train.

The following information is gathered during the Analysis Phase:

1. Requirements as per the customer's technical specification
2. Details of the wayside infrastructure and operating environment
3. Applicable standards and statutory EMC regulations
4. EMC performance data of all equipment to be installed on the train
5. Car body design features and materials used
6. Experience and lessons learned from previous railway projects

2.1.1 Customer Technical Specification

ICF Specification No.: ICF MD SPEC-447, ISSUE STATUS-01,REV-00,DATE-03-02-2025:
SPECIFICATION FOR STANDARD GAUGE HIGH SPEED TRAINSET

2.1.2 Infrastructure Requirements

Requirements related to the railway infrastructure include the following:

1. Power Supply : Specifications are based on customer requirements and practical measurements taken at substations where the trains will operate.
2. Wayside Communication Equipment : This includes systems such as train radio and telecommunications, as defined in the technical specifications.
3. Signaling Systems : These must comply with the requirements outlined in the applicable specifications to ensure proper electromagnetic compatibility between the train and trackside systems.

2.1.3 Standards and Statutory regulation

The EMC requirements apply to all systems, components, and modules that fall within the scope of the relevant standards. These include, but are not limited to, the following:

- EMC Product Standards:
 - EN 50121-1 (IEC 62236-1): General EMC requirements

- EN 50121-3-1 (IEC 62236-3-1): Rolling stock – Train and complete vehicle
- EN 50121-3-2 (IEC 62236-3-2): Rolling stock – Apparatus

These are applied in conjunction with the EMC basic standards series:

- EN 61000-4-2: Electrostatic discharge immunity
- EN 61000-4-3: Radiated RF electromagnetic field immunity
- EN 61000-4-4: Electrical fast transient/burst immunity
- EN 61000-4-5: Surge immunity
- EN 61000-4-11: Voltage dips, short interruptions, and voltage variations immunity
- Design and Testing Requirements:
 - IEC 60571: Electronic equipment used on rolling stock
- Demonstration of Compatibility:
 - EN 50238-2 and EN 50238-3: Compatibility between rolling stock and railway signaling and telecommunications systems
 - EN50500- Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure

2.2 *Synthesis Phase*

The synthesis phase typically comprises two interdependent activities aimed at achieving electromagnetic compatibility between all the equipment fitted in vehicle including foreign equipment, as well as compatibility with the general railway environment:

- EMC Management: Involving administrative and organizational activities.
- EMC Design: Involving technical rules, design principles, and implementation commitments.

2.2.1 EMC Design Measures

- Equipment must operate reliably in environments subject to both low and high frequency electromagnetic disturbances.
- Installation and design must comply with applicable functional and safety requirements.
- Electromagnetic disturbances must be limited to levels that do not pose a safety risk to other systems.
- Effective installation practices are often a practical and efficient way to achieve the desired immunity levels.

2.2.2 Generic Design Rules

To ensure EMC, the following strategies are applied based on the three-part model of source coupling path susceptible equipment:

- At the source: Emission is minimized through proper equipment design.
- At the coupling path: Coupling is mitigated by increasing impedance or isolation.

- At the susceptible device: Immunity is enhanced through shielding, grounding, and filtering.

General design rules include:

- Definition and use of EMC zones
- EMC-related grounding (with clear distinction between protective and functional earthing)
- Shielding of cables and appropriate cable earthing
- Shielding of enclosures
- Cabling practices, including routing, segregation, and screening
- Proper selection and installation of EMI filters

These guidelines provide a unified approach to ensure that electromagnetic interference is controlled and does not impair the vehicle's operational performance.

2.2.3 Particular EMC Measures

Project-specific EMC compatibility and feasibility studies are conducted with special focus on:

- Signaling systems
- Communication systems
- Train control systems
- 25 kV OHE system

These assessments ensure that interaction between onboard systems and trackside infrastructure is effectively managed.

2.2.4 Final Design for EMI/EMC

The final EMI/EMC design takes into account the following parameters:

- Location of equipment (e.g., inside passenger compartments, high-noise zones, or externally mounted)
- Sensitivity of the equipment to electromagnetic disturbances
- Characteristics of interfaces with other onboard or infrastructure systems

2.2.5 Manufacturing process

During manufacturing, strict adherence to EMC best practices is essential. These include:

- Ensuring adequate cable shielding and grounding
- Use of proper filtering techniques
- Implementation of optimal equipment layout and physical separation
- Verification of EMC compliance during and after installation

2.3 *Validation Phase*

The validation phase confirms Electromagnetic Compatibility (EMC) compliance through both system-level and train-level testing. All test procedures and results are documented to support final

acceptance and certification.

2.3.1 Tests on System Level

For each equipment item, a specific EMI/EMC test protocol shall be defined. Testing shall be performed either in-house at the manufacturer's facilities or at a third-party laboratory approved for EMC compliance evaluation.

All test results must be formally documented in dedicated EMI/EMC test reports, including test conditions, limits, measurement setups, and observed results.

2.3.2 Tests on Train Level

Train-level EMC tests are conducted to verify proper operation and electromagnetic compatibility of the fully integrated trainset. These tests are subdivided as follows:

- Internal Interfaces: Verifying interactions among onboard subsystems and confirming that no unintended interference exists between components.
- External Interfaces: Verifying compatibility between the train and its surrounding electromagnetic environment, including infrastructure systems such as signaling, power supply, and communications.

These tests are based on the finalized “As-Built” EMC design of the train and assume that all individual systems have successfully passed type tests and meet their validated EMC requirements.

Additional integration or verification tests may be conducted based on the specific approval process defined by the customer or certification authority.

2.3.3 Demonstration of Compliance

All EMI/EMC tests both at the system and train level shall be conducted according to the respective approved test protocols. It shall be verified that all measured values comply with the applicable limits specified in the relevant EMI/EMC standards.

Documented evidence of test results, compliance statements, and any deviations (if applicable) shall form part of the overall EMC validation dossier.

3 Train Overview

One basic unit of 4-car unit is the building block for Train Set rake formation. Each basic unit consists of one Driver Trailer Coach (DTC) at the end, two Motor Coaches(MC) and one Trailer Coach (TC).

Two such basic units can be coupled together to form one rake of 8 coaches. Formation of basic unit is shown below:

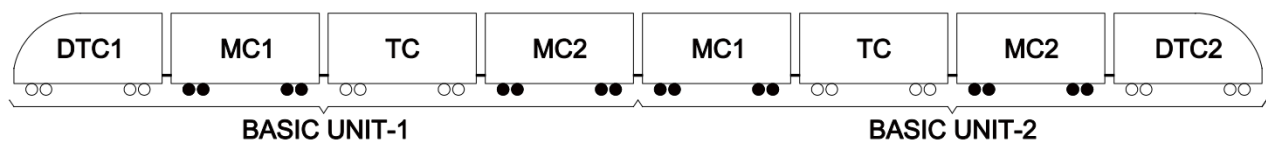


Figure 1: Train Formation

Driving Trailer Coach (DTC) is a non-powered vehicle with a Driver cab at one end. The Driver cab is furnished with a pre-fabricated Driver Desk. All driving operations are possible from Driver Desk. Feedback from all systems in all the coaches / basic units is available for viewing on the Driver Desk and certain functionalities can be controlled from the Driver Desk. In this regard a 10.4" Touch Based TFT display is provided on driver desk for showing combined status. Various gauges and indications are also provided on driver desk for knowing MR, BC and parking brake pressure. The driver will also be able to control/operate the Passenger Information System, Train Radio from the Driver Desk. It also consists of LVPS with battery charger & battery and main air compressor which are mounted underslung. Rest of the DTC apart from the Driver cab is Passenger saloon area and vestibules. Two electrical cabinets are placed in rear wall of driver cab and one more electrical cabinet at non driving end. All passenger comfort related loads can be controlled by driver from driver cab.

Motor Coach (MC) is a powered vehicle with one Traction Motor driving each axle. The Motor Coach contains a line and traction converter unit (LTC) for each bogie mounted underslung. Transformer secondary cable for both LTC units comes from power transformer mounted in Trailer Coach through underslung mounted IV Coupler. It also consists of 2 no's electrical cabinets.

Trailer Coach (TC) contains a pantograph, vacuum circuit breaker, surge arrestors and isolator on roof. It also consists of auxiliary converter units and power transformer mounted underslung. Power to LTC units of both motor coaches is distributed from same power Transformer through Power Coupler. It also consists of 2 no's electrical cabinets.

In trailer coach there are 2 variants i.e TC coach in basic unit 2 is for executive class and the TC coach in basic unit 1 is for standard class.

All the passenger saloon areas are provided with air condition, controlled using HVAC(2no's) units mounted in each coach. All electrical cabinets, driver desk and passenger saloon areas are provided with fire detection equipment.

All the coaches are provided 4no's of airtight plug type exterior doors for passenger entry/exit. In addition all coaches are provided with automatic internal doors duly segregating passenger saloon area and door way vestibule area.

All the coaches including driver cab are provided with CCTV cameras and passenger information system.

4 Various Equipment and EMC Measures

S.No.	Sub-system	Location	EMC Measures
1	Traction Transformer	Trailer Coach, Underframe	Section 6.6.2
1.1	Oil pumps (3 Phase AC)	Trailer Coach, Underframe	Section 6.3.3
1.2	Radiator Blower (3 Phase AC)	Trailer Coach, Underframe	Section 6.3.3
1.3	Temperature Sensors	Trailer Coach, Underframe	Section 6.3.10, 6.5.1
1.4	Level Switch / Pressure Switch / Flow Switch	Trailer Coach, Underframe	Section 6.3.10
1.5	MPCB	Trailer Coach, Underframe	Section 6.3.5
1.6	Contactor	Trailer Coach, Underframe	Section 6.3.5
2	Traction Converter	Motor Coach, Underframe	
2.1	Traction Converter cubicle (TCC)	Motor Coach, Underframe	Section 6.3.7, 6.6.1
2.2	Traction Motor Control Computer (TIC) and Line Converter Control Compute(LIC) with interface with MCU	Motor Coach, Underframe	Section 6.3.9
2.3	Line converter related IGBT, Current sensor, Gate Drive card, Voltage sensor	LTC, Under frame, Motor coach	Section 6.3.7, 6.3.10, 6.5.2
2.4	Traction inverter related IGBT, Current sensor, Gate Drive card, Voltage sensor	LTC, Under frame, Motor coach	Section 6.3.7, 6.3.10, 6.5.2
2.5	Brake Chopper related IGBT, Gate Drive Card, Current sensor	Under frame, Motor coach	Section 6.3.7, 6.3.10, 6.5.2
2.6	Brake Chopper resistor	Under frame, Motor coach	Section 6.3.7
2.7	DC Link Capacitor	Under frame, Motor coach	Section 6.3.7

S.No.	Sub-system	Location	EMC Measures
2.8	Radiator Blower (3 Phase AC) / Oil pump (3 Phase AC)	Under frame, Motor coach	Section 6.3.3
2.9	DC Discharge Switch	LTC, Under frame, Motor coach	Section 6.3.7
3	Traction Motor Drive		
3.1	Traction Motor with termination box and pinion mounted	Underframe, Motor coach	Section 6.3.3, 6.6.3
3.2	Speed and temperature sensors	Underframe, Motor coach	Section 6.3.10, 6.5.1
4	Electrical panel		
4.1	End wall panel	CRW in DTC ECC MC and TC	Section 6.3.2
4.2	Central Control Unit (CCU)	CRW in DTC	Section 6.3.9
4.3	Passenger Comfort Control Unit (PCU), Main Control Unit (MCU)	CRW in DTC, ECC in MC and TC	Section 6.3.9
4.4	ECN switch	All coaches	Section 6.3.9
4.5	ETB Switch	ECC in MC1, TC	Section 6.3.9
4.6	MCBs	Driver Cab, DTC- electrical panel, DTC	Section 6.3.5
4.7	Relays	Driver Cab, DTC- electrical panel, DTC	Section 6.3.6
4.8	Other Control Units	DTC panel, DTC	Section 6.3.9
5	Auxiliary Converter		
5.1	Auxiliary Converter cubicle	Under frame, Trailer coach	Section 6.3.7, 6.6.1, 6.3.9, 6.6.4
5.2	Aux Converter related IGBT, Current sensor, Gate Drive card, Voltage sensor	Aux-Converter, Under frame, Trailer coach	Section 6.3.7, 6.3.10, 6.5.1
5.3	MCB panel	Aux-Converter, Under frame, Trailer coach	Section 6.3.5
5.4	Contactor Panel	Aux-Converter,	Section 6.3.5

S.No.	Sub-system	Location	EMC Measures
		Under frame, Trailer coach	
5.5	Cooling Blower (3 phase)	Aux-Converter, Under frame, Trailer coach	Section 6.3.3
6	Air Supply System		
6.1	Air compressor (3 Phase)	Under frame, DTC	Section 6.3.3
7	Brake panel interfacing		
7.1	Pressure sensors, pressure switches and Actuators (magnet valves)	EP Unit, Underframe, all coaches,	Section 6.3.10, 6.5.1
7.2	EBCU	CRW in DTC, ECC in MC and TC	Section 6.3.9
8	Driver Desk		
8.1	Driver Desk including all controls, indications, gauges, back lit instrumentation panel, pre-wired and terminated on terminal board and multi-pin sockets/plugs for inter- equipment connections	Driver cab in DTC	Section 6.3.2
8.2	Master controller for Driver Desk	Driver cab in DTC	Section 6.3.2, 6.6.6
8.3	Pneumatic indication gauges, TFT display.	Driver cab in DTC	Section 6.3.2, 6.3.9, 6.6.6
8.4	Cab equipment: ETCS/TCAS, pneumatic horns, wind screen wipers, head light, tail light	Driver cab in DTC	Section 6.3.2, 6.6.5, 6.6.6
8.5	Switches and lamps	Driver cab, DTC	Section 6.3.2
9	Passenger Information System and Infotainment System (Ethernet based)		
9.1	MCP and mic	Driver Cab, DTC	Section 6.3.9

S.No.	Sub-system	Location	EMC Measures
9.2	Car Controller (CC)	CRW in DTC and ECC in MC,TC	Section 6.3.9
9.3	Saloon Loud Speakers	Passenger area	Section 6.6.6
9.4	Cab Loud Speakers	Driver cab	Section 6.6.6
9.5	LCD display	Passenger area	Section 6.3.9
9.6	Side Destination Board Unit(SDBU)	Passenger area	Section 6.3.9
9.7	ETBU, IFTCU	Passenger area	Section 6.3.9
9.8	GPS Antenna & Receiver	On roof, DTC	Section 6.3.11
10	CCTV		
10.1	CCTV Display	Driver Cab, DTC	Section 6.3.9
10.2	CCTV PIS ECN Switch	ECC in MC, TC	Section 6.3.9
10.3	MAR, CHM	ECC in DTC	Section 6.3.9
10.4	NVR	ECC in MC, TC	Section 6.3.9
10.5	Internal camera	Passenger area, driver cab	Section 6.6.6
10.6	Exterior cameras(track view camera)	DTC	Section 6.6.6
11	Load weighing system		
11.1	pressure sensor	Underframe of DTC,MC and TC	Section 6.3.10, 6.5.1
12	Inter-vehicular Couplers and jumper cable/connectors	Under frame DTC, MC and TC	Section 6.6.5
13	Lightning Arrestors	On roof, TC	Section 6.2.1
14	Vacuum Circuit Breaker + Earthing switch	On roof, TC	Section 6.3.5
15	Auxiliary compressor	Under frame TC	
18.1	Auxiliary compressor	Under frame TC	Section 6.3.3
18.2	Pressure governor, panto air supply isolation cock	Under frame TC	Section 6.3.5
16	Lights	Passenger area of all coaches	Section 6.3.4, 6.6.6
17	FDS	all coaches	

S.No.	Sub-system	Location	EMC Measures
17.1	Fire Alarm Control Panel (FACP)	CRW in DTC, ECC in MC	Section 6.3.9
17.2	Linear Heat Detection Unit (LHDU)	CRW in DTC, ECC in MC	Section 6.3.10
17.3	Smoke and heat sensors	Passenger Area of all coaches	Section 6.3.10
18	HVAC	On roof, All coaches	Section 6.3.8, 6.3.9, 6.3.10, 6.3.11
19	Plug door	Passenger Area of all coaches	Section 6.3.8, 6.3.9, 6.3.10, 6.3.11
20	IC door	Passenger Area of all coaches	Section 6.3.8, 6.3.9, 6.3.10
21	Measuring Equipment		
	Panto measuring equipment	On roof, TC car	Section 6.3.8, 6.3.9, 6.3.10, 6.3.11
	Track Measuring equipment	Underframe, TC car	Section 6.3.8, 6.3.9, 6.3.10
	Cabinet for Measurement unit	On board, TC car	Section 6.3.8, 6.3.9, 6.3.10, 6.3.11
22	CBMS		
	Vibration Sensor	All coaches Underframe	Section 6.3.10
	Bogie System Module	All coaches Underframe	Section 6.3.9, 6.3.11
	CMS RV	All Coaches On board	Section 6.3.9, 6.3.11
	Edge Server	DTC Coach On board	Section 6.3.9, 6.3.11
23	Batteries (110V) and Battery box	Under frame of DTC	Section 6.6.4
24	Battery Charging System	Under frame of DTC	Section 6.6.4
25	All power and signal Cables	All the coaches	Section 6.6.3, 6.3.11
26	All communication and data cables	All the coaches	Section 6.3.11

Table 3: EMI/EMC measures for various equipment of Trainset

5 EMC Management

5.1 General

Effective EMC management is essential for ensuring electromagnetic compatibility throughout the lifecycle of the project. Proper control of EMC can only be achieved by implementing defined measures at each stage of the project execution. The key phases include:

- **Design Phase :** EMC-related issues must be identified during the design phase. Maximum care should be taken to incorporate mitigation strategies into the product design to prevent electromagnetic interference at the source.
- **Assembly and Production Phase :** At this stage, it must be ensured that all EMC measures proposed during the design phase are properly implemented and verified during production.
- **Field Installation Phase :** This is one of the most critical phases in EMC management. At this point, all external factors contributing to electromagnetic interference must be evaluated, and appropriate installation practices should be adopted such as physical separation of signal and power lines, cable shielding, proper grounding, and segregation of EMI-sensitive components.
- **Validation Phase :** This is the final stage of EMC management, which confirms that the EMC measures implemented during all previous project phases are effective and performing satisfactorily under actual operating conditions.

In addition, it must be ensured from the initial phase that all equipment procured from external vendors is also designed and installed in accordance with the EMC Plan.

5.2 Responsibilities

5.2.1 Purchaser activities

The active participation and support of the Purchaser (i.e., NHSRCL/ICF) is essential throughout the project. If the information provided in the customer specifications is found to be insufficient for defining detailed EMC design requirements, Medha will formally request additional data.

Unless otherwise specified in the contract, the Purchaser will be responsible for supplying or assisting in gathering accurate information regarding the electromagnetic and operational environment in which the system will be deployed.

5.2.2 Supplier activities

The supplier is responsible for delivering systems and equipment that meet the applicable EMC specifications and align with safety and reliability targets.

All subcontractors to Medha, as well as BEML, are required to support the identification of EMC critical components and contribute toward achieving the EMC objectives. In defining the electromagnetic environment of a system composed of multiple subsystems, each subcontractor supplying electrical and electronic equipment must provide the necessary technical data.

Additionally, Medha/BEML will identify all EMC critical equipment, particularly those related to the control computers of:

- Propulsion systems

- TCMS (Train Control and Monitoring System)
- Auxiliary power systems
- Brake systems
- Door control systems
- Fire detection systems (FDS)
- Passenger Information Systems (PIS)
- Other control systems

EMC design and planning for these systems will be initiated from the start of the project, as detailed in Section 5.1.

To ensure the successful implementation of the EMC Plan, the following activities shall be carried out:

- Define EMC related risks and constraints for all major systems
- Develop an EMC Control Plan to address identified risks
- Incorporate EMC considerations into product design, system engineering, and field installation plans
- Submit detailed EMI/EMC Test Plans, procedures, and reports
- Monitor the implementation of EMC measures during field installation
- Submit EMI/EMC test reports in accordance with approved EMC test protocols for various control systems
- Perform final EMC validation at the Trainset rake level

6 Sources of EMI

Refer to **EN 50121-1** for a comprehensive definition of the railway network and various sources of Electromagnetic Interference (EMI).

6.1 *General notes*

In many cases, the same equipment can function both as a source of EMI and as a receiver of such interference. These roles are often inseparable, and measures to control emissions frequently also enhance immunity.

As a result, the EMC control strategies described below are intended to address both emissions and susceptibility sometimes focusing on one, and sometimes addressing both simultaneously. This is particularly relevant for train-borne equipment, where different components located in close proximity may interfere with each other.

Likewise, for interference involving external sources, the same mitigation techniques often provide protection in both directions.

6.1.1 Faraday Cage Concept

Ideally, enclosing all equipment within a perfect “Faraday cage” would eliminate emissions and provide high immunity to external interference. In practice, such ideal shielding cannot be fully realized. Equipment cubicles inside control cabinets may act as imperfect Faraday cages due to the presence of wiring and cabling that extends outside, which can serve as pathways for interference currents or in some cases as antennas radiating electromagnetic energy.

For EMI originating from the supply line or wayside equipment, the control cabinet itself is an imperfect Faraday cage. Cables entering the cabinet has transmission paths for EMI. Long wiring and cabling routes along the train can behave as large antennas, picking up interference from multiple locations, thereby compromising shielding.

EMC design measures are often aimed at restoring or approximating the Faraday cage concept especially at system and subsystem boundaries such as where cables enter cubicles or control cabinets, or where enclosures are opened. Restoration of the Faraday cage effect is most effective at these interface points.

6.1.2 General EMC Control measures

General EMC control measures to reduce interference between subsystems include:

- Reducing emissions at the source through proper shielding, filtering, and grounding
- Improving system immunity by using EMC filters, shielding, and reliable grounding techniques

6.2 *Interference Originating in the Supply Network*

Some types of EMI originating from the supply network may not fall directly within Medha’s scope, as their control may depend on the coach builder or infrastructure provider. However, common causes and their mitigation approaches are described below.

6.2.1 Lightning discharge

Lightning strikes can inject high currents with steep rates of change (di/dt) into the supply system,

resulting in potentially damaging transient overvoltages.

Interference Pathways:

- Wiring and cabling entering high-tension (HT) equipment from the roof
- Line voltage sensors and line current sensors

Control Measures:

- Use of surge arresters on the overhead line to absorb energy and reduce impulse voltage
- Isolation of components directly connected to the overhead line to withstand residual impulse
- Ensuring that cabling connected to the supply line is not terminated inside HT equipment compartments

6.2.2 Contact Bounce from a Pantograph

Contact bounce or arcing at the pantograph results in fast voltage fluctuations, high-frequency electromagnetic fields, and overvoltage transients.

Interference Pathways:

- Line voltage and current sensors

Control Measures:

- Voltage tolerant design of equipment, including appropriate filters
- Onboard battery systems to back up control voltages during disturbances
- Isolation transformers for accurate voltage measurement
- Ensuring good insulation of components connected to the overhead line
- Avoiding termination of supply line cabling within the HT room

6.2.3 Interrupted Power Return Bonding in a Railway Track

Discontinuities or high impedance in the return current path can cause transient voltage differences between electronic components, or high shield currents.

Control Measures:

- Installation of power return cables with sufficient cross-section between coaches to maintain equipotential bonding and prevent loop currents
- Ensuring proper track bonding and regular track maintenance

6.2.4 Power Supply Fluctuations from Substations or Other Vehicles in the Same Section

Rapid voltage changes or supply instability caused by switching operations or multiple trains in the same section can result in EMI.

Interference Pathways:

- Cabling entering the HT area from the roof

- Voltage sensing equipment

Control Measures:

- Voltage-tolerant design, incorporating appropriate filtering
- Battery backup to ensure stable control voltages
- Proper sizing of substation power supplies
- Ensuring sufficiently low line impedance in the traction network

6.3 Interference Originating in Train-Borne Equipment

This type of interference is primarily transmitted through cabling and wiring within the train. Depending on its source, the interference may be intermittent (e.g., caused by switching operations) or continuous (e.g., originating from converters, power supplies, or lighting systems).

Interference between onboard systems is addressed during the design phase of the electrical installation through the implementation of targeted EMC control measures.

Based on their characteristics and EMI behavior, sources of electromagnetic interference are categorized into the following equipment groups.

6.3.1 Grouping of EMC Relevant Equipment

Equipment is divided into groups that require similar EMC mitigation strategies. These groups are discussed in the following subsections:

- a) Operator Equipment
- b) Electric Motors (Traction and Auxiliary Motors)
- c) Lightning Arresters
- d) Power Switches and Contactors
- e) Relays
- f) Power Electronic Equipment
- g) Switched Mode Power Supplies (SMPS)
- h) Various Control Computers
- i) Sensors
- j) Control Networks

6.3.2 Operator equipment, Electrostatic discharge (ESD)

Electrostatic discharge (ESD) is a common source of interference in operator interfaces such as push buttons, touchscreens, and control panels that are directly accessible to the user. These components are often sourced from third-party vendors.

EMC Control Measures:

- Careful selection of operator interface equipment
- Compliance with relevant EMC and ESD standards
- Proper grounding of equipment housings and control surfaces

6.3.3 Electric Motors

Traction motors are fully suspended and under-slung. These motors operate using high-frequency power sources, which may affect nearby sensors, particularly speed and temperature sensors.

EMC Control Measures:

- Separation of sensor wires from high-power cables
- Use of shielded sensor cables with proper earthing
- Routing of sensor cables in dedicated cable ducts
- Ensuring cable ducts are properly earthed at multiple points
- Implementation of fault-tolerant logic in sensor value processing, especially for speed sensing
- Incorporation of filters in sensor input circuits
- Routing of all phase and neutral conductors together to minimize emitted magnetic fields
- Increasing voltage rise time for high-power motors using passive filters or by reducing semiconductor switching speed to enhance insulation lifetime and reduce electromagnetic interference

6.3.4 Lighting Systems

Lighting systems can produce high-frequency interference, particularly during switching, which may resemble electrical bursts.

EMC Control Measures:

- Selection of lighting equipment equipped with certified EMC filters
- Compliance with relevant EMC standards for lighting systems to ensure acceptable interference levels
- Shielding of wires connected to sensitive equipment
- Routing of wiring through well-grounded cable ducts

6.3.5 Power Switches / Contactors

The primary source of interference in power switches and contactors is the high-current turn-off, which generates energetic surge voltages in the power cabling. Transmission paths include power and control cables, or inductive coupling into adjacent conductors. Additionally, energizing coils contribute to EMI, with voltage spikes occurring during turn-off and current surges during turn-on.

EMC Control Measures:

- Use of voltage-tolerant power systems and well-designed isolation strategies
- Adequate separation between power and control cables
- Routing of power and control wiring through separate, well-grounded cable ducts
- Avoiding parallel routing of power and control cables where possible, to minimize inductive coupling
- Equipping all energizing coils with peak-voltage reduction devices, such as properly

dimensioned RC filters, back-to-back Zener diodes, transient voltage suppressors, or free-wheeling diodes

- Using conductors with sufficient cross-section to carry surge currents without introducing significant voltage drops
- Implementing fault-tolerant logic, including filtered and isolated logic inputs, surge-resistant logic outputs, and an electrically robust design

6.3.6 Relays

Interference in relays is primarily caused by voltage spikes and high-frequency emissions that occur during the sudden turn-off of inductive currents in relay coils. These disturbances are typically transmitted through control wiring. Additionally, surge currents at the moment of turn-on can cause voltage sags that propagate through battery-powered systems.

Relays are usually connected to train lines, which are often unshielded. Therefore, they must be handled with special care to prevent the propagation of switching-related interference. Due to its quasi-random nature, interference from unprotected relay coils can result in difficult-to-diagnose malfunctions and, in some cases, may cause permanent damage to sensitive electronic circuits.

EMC Control Measures:

- All relay coils shall be equipped with free-wheeling diodes, back-to-back Zener diodes, transient voltage suppressors, or properly dimensioned RC damping filters to suppress voltage spikes
- Train line wires shall be routed through metallic cable ducts with multiple earthing points, including grounded metal covers, to ensure effective shielding
- Train wires shall be laid along earthed metallic parts of the train body and cubicles, utilizing distributed capacitance for natural EMI filtering
- Non-shielded wires operating at battery voltage shall be kept physically separate from sensitive sensor wires, signaling cables, and critical communication networks. These cables must not be placed within the same section of cable ducts
- Non-shielded wires shall also be segregated from power electronic cables to avoid electromagnetic coupling, including coupling at 50 Hz
- Fault-tolerant logic design shall be used, incorporating filtered logic inputs, surge-resistant outputs, and a robust electrical architecture
- Cable ducts shall remain uninterrupted and electrically bonded throughout their length, with wide contact surfaces to ensure low-impedance grounding continuity
- Cables shall be segregated by function e.g., high-voltage lines, 415 V AC power, 110 V DC train lines, sensor cables, communication lines, and audio circuits with proper spacing maintained between categories

6.3.7 Power Electronic Equipment

Electromagnetic interference from power electronic equipment is primarily caused by frequent high-power switching actions. This results in continuous interference during equipment operation, which, if not properly mitigated, can propagate along power and signal cabling.

In addition to affecting nearby equipment, power electronic systems can adversely impact motors by introducing additional losses and generating common-mode currents through motor bearings. Notably, some EMC control measures implemented to limit interference also provide added protection for motors and auxiliary systems.

EMC Control Measures:

- The enclosure shall be earthed at a minimum of two points, ensuring that interference currents are diverted into the vehicle body instead of propagating through power cables
- Shields on signal wires shall be connected directly to the enclosure wall using extremely short, appropriately gauged conductors; internal and external shield connections should be bonded where possible
- Non-shielded wires entering the enclosure shall be routed closely along the conductive enclosure walls to facilitate dissipation of interference currents through distributed capacitance
- Power electronic systems shall support a wide operating voltage range and must tolerate low-frequency disturbances caused by input voltage fluctuations
- Galvanic isolation between power and control circuits shall be implemented with low coupling capacitance to minimize conducted interference
- Control logic shall be designed to be fault-tolerant and electrically robust
- Power cables shall be routed in metallic cable ducts with multiple earthing points and grounded metal covers to ensure effective shielding
- Cable ducts must be continuous and electrically bonded with wide contact surfaces to ensure low-impedance grounding
- The output voltage rate-of-change (dv/dt) of power electronic systems shall be controlled to reduce high-frequency emissions and insulation stress
- Traction motors shall be equipped with isolated bearings to prevent bearing currents, which could otherwise lead to pitting or premature failure
- Return conductors and/or pilot wires shall be routed together with corresponding feed conductors in a single bundle to minimize loop area and magnetic field emissions
- Sine-wave filters shall be used on auxiliary power supplies to reduce harmonic distortion and minimize excess motor heating
- Auxiliary power supplies shall be galvanically isolated to suppress common-mode voltages and reduce insulation stress on auxiliary motors
- Cable lengths between power electronic outputs and motors shall be kept as short as practically possible to limit both conducted and radiated emissions
- Unprotected power cables shall not be routed near sensitive wiring
- Feeder and return conductors shall be routed together and should enter cubicles through a single cable gland to reduce magnetic coupling
- If separate cable glands are necessary, non-magnetic gland plates shall be used to prevent magnetic interference

- To control the switching harmonic current on primary of Transformer i.e. on 25 kV AC line due to switching in Line and Traction converter, proper interlacing is done between firing angle of IGBT of Line converter of various unit based on number of active LTC per rake.

6.3.8 Switched Mode Power Supplies (SMPS)

All power supply modules used in control units are Switched Mode Power Supplies (SMPS). Likewise, all onboard DC-DC converters follow the SMPS architecture. These units can generate electromagnetic interference over a wide range of frequencies. Since SMPS units are typically connected directly to the vehicle's 110V DC battery using non-shielded wiring, the resulting interference may propagate across the vehicle's electrical system if not properly mitigated.

EMC Control Measures:

- All SMPS units whether standalone or integrated into control computers are equipped with input filters to suppress EMI. Each unit includes both common-mode and differential-mode filtering
- All Medha-designed SMPS modules used in control computers are enclosed in well-earthed mild steel (MS) housings to provide effective electromagnetic shielding. An integrated common-mode filter is also used to suppress conducted noise on the 110 V DC line
- Onboard SMPS units are designed to operate over a wide input voltage range to accommodate supply fluctuations
- All SMPS units incorporate galvanic isolation between input and output to prevent ground loops and enhance both EMC performance and electrical safety
- Switching speeds are optimized and controlled to minimize the frequency spectrum of emitted interference
- Control inputs are electrically isolated to avoid signal coupling and cross-interference
- The overall system is designed with a robust electrical architecture to ensure reliable performance in harsh electromagnetic environments
- Ground planes are engineered with care to manage return current paths and reduce noise coupling
- Multiple earthing points are employed on the ground plane to ensure low-impedance discharge paths for interference currents and improve overall EMC performance

6.3.9 Control Computers

The control boards used in all control computers typically include high-frequency crystal oscillators, which can generate high-frequency emissions that propagate through the connected wiring and affect surrounding systems.

EMC Control Measures:

- Ground planes on all printed circuit boards are carefully designed to manage return current paths and reduce noise coupling
- Internal and external grounds are electrically isolated to prevent propagation of interference
- All input/output (I/O) signals are filtered to limit bandwidth and suppress high-frequency noise

- I/O signals are isolated to avoid ground loops and improve signal integrity
- All control boards are enclosed in mild steel (MS) housings, with proper grounding of the enclosures to ensure shielding effectiveness and containment of emissions

6.3.10 Remote Sensors

Sensors are particularly vulnerable to electromagnetic interference (EMI) due to several factors: sensor signals are typically low-level and noise-sensitive; sensor cables are often long; and sensors may operate in harsh environments characterized by extreme temperatures, shock, vibration, strong magnetic fields, and exposure to contaminants such as dust and moisture.

EMC Control Measures:

- Selection of sensor types with a proven track record for reliable performance in EMI-prone environments
- Use of shielded cables for all sensor connections to minimize electromagnetic pickup
- Ensuring the shield is continuous and properly bonded throughout the entire cable length
- Routing of sensor cables through metallic conduits or ducts, with proper earthing at multiple points to enhance shielding performance
- Physical segregation of sensor cables from power cables to minimize magnetic and capacitive coupling
- Use of EMI filters in sensor interface circuitry to block unwanted frequencies and preserve signal quality

6.3.11 Communications

Control communication wiring is often similar in structure and vulnerability to remote sensor cabling both typically involve long runs of shielded twisted-pair cables transmitting low-voltage signals. However, communication cables may connect multiple nodes along the network, increasing their exposure to noise and interference. Given the critical role of communication in system control and safety, such networks are often designed with redundancy at the physical layer.

EMC Control Measures:

- Use of shielded twisted-pair cables to reduce susceptibility to external electromagnetic interference
- Ensuring continuous shield integrity along the full length of the cable, with proper bonding at both ends
- Routing of communication cables through metallic ducts or conduits, with multiple grounding points to enhance shielding effectiveness
- Adequate physical segregation from power and high-voltage cables to prevent coupling of high-frequency noise or transient interference
- Use of intermediate repeaters or signal isolators for long cable runs to maintain signal quality and prevent the accumulation of interference
- Implementation of robust communication protocols incorporating Cyclic Redundancy Check (CRC) or similar error-detection mechanisms to identify and discard corrupted

messages

6.4 Interference Originating Outside the Vehicle

Electromagnetic interference (EMI) can also originate from external sources that are not part of the train's onboard systems. These include:

- Mobile communication devices used by passengers or staff
- Other trains operating on parallel tracks or within the same traction section
- Wayside infrastructure such as high-power transmitters, substations, signaling equipment, or nearby industrial installations

Such interference may be radiated or conducted, and can affect the performance of onboard communication systems, control electronics, or sensitive measurement devices.

EMC Control Measures Against External Interference:

- Use of Faraday cage principles by enclosing electronic control units within metal cubicles to block external electromagnetic fields
- Routing wires and cables exiting control cabinets through earthed cable ducts, aligned along metallic structural parts, with multiple earthing points to enhance shielding effectiveness
- Application of filters and/or galvanic isolation at the inputs of electronic units to suppress both conducted and radiated interference

6.5 Susceptible Parts

Certain components within the vehicle are inherently more susceptible to electromagnetic interference and must be given special attention during the design and installation process.

6.5.1 Speed Sensors and Temperature Sensors

Speed sensors are particularly vulnerable to EMI due to several contributing factors:

- Long cable lengths
- Low signal amplitude
- High signal frequencies
- Proximity to traction motor high-current power cables

Control Measures:

- Use of properly shielded cables with shield continuity maintained over the entire length
- Routing of sensor cables through earthed metallic ducts or conduits for effective shielding
- Incorporation of filters within sensing circuits to suppress high-frequency noise

6.5.2 Line-Voltage and Line-Current Sensors

Line-voltage and line-current sensors are susceptible to interference because they interface with high voltage systems while generating relatively low level output signals.

Control Measures:

- Use of voltage transformers with low winding capacitance to reduce capacitive coupling
- Integration of filters into sensing circuits to attenuate high-frequency disturbances
- Design of current sensors with low coupling capacitance to reduce susceptibility to both common-mode and differential-mode noise

6.6 Interference Pathways

Electromagnetic interference can enter and propagate within the train through specific physical pathways. Identifying and mitigating these paths is essential for ensuring EMC compliance and safe operation.

6.6.1 HV Cabling routing through Onboard pathway

When high-voltage (HV) cabling is routed through On board path to underframe, it can serve as a conduit for high-voltage electromagnetic interference originating from the overhead contact line, allowing it to enter on board area and affect nearby systems.

Control Measures:

- Route such cables through separate, well-earthed cable ducts or conduits with multiple grounding points
- Minimize the length of HV cables to reduce the exposure and coupling potential
- Terminate cables through appropriately rated EMI filters to block conducted interference
- Install HV cables in conductive trays grounded at multiple points to dissipate EMI safely
- Avoid parallel routing of other cables alongside HV cables to reduce the risk of induced interference
- Maintain clear physical separation between HV cables and all other wiring to prevent capacitive or inductive coupling

6.6.2 The HV Transformer

The high-voltage transformer can serve as a coupling path for EMI through its windings, especially via capacitive coupling from the supply line.

Control Measures:

- Install filters in all sensing and monitoring circuits connected to the transformer to suppress high-frequency noise
- Maintain adequate physical separation between transformer-associated cabling and other signal or control lines to reduce the risk of cross-coupling

6.6.3 Power Cables for the Traction System (Inputs and Outputs)

Power cables associated with the traction system can carry high levels of interference currents due to the switching activity of power electronic devices and contactors. These cables often run across long distances within the vehicle, increasing the risk of EMI propagation.

Control Measures:

- Minimize cable lengths wherever feasible to reduce EMI exposure
- Keep feeder and return cables tightly bundled to minimize the formation of external magnetic fields
- Avoid running other cables in parallel with these power cables
- Where parallel routing is unavoidable, use separate, well-earthed cable ducts to isolate power cables from signal or control wiring

6.6.4 Power Cables for the Auxiliary Converter and Distribution Network

Power cables associated with the auxiliary converter can carry high levels of interference currents due to the switching activity of power electronic devices and contactors. These cables often run across long distances within the vehicle, increasing the risk of EMI propagation.

Control Measures:

- Minimize cable lengths wherever feasible to reduce EMI exposure
- Keep feeder and return cables closely bundled; in three-phase systems, route phase and neutral conductors together
- Use sine-wave filters on the output side to minimize harmonic distortion in the AC voltage
- Avoid running other cables in parallel with auxiliary power cables where possible
- Where parallel routing is unavoidable, ensure proper segregation using separate, well-grounded cable ducts
- Route three-phase conductors along with the neutral through a single cable gland whenever possible. If separate glands are used, employ non-magnetic gland plates to avoid magnetic interference

6.6.5 Non-Shielded Train Wires

Non-shielded train wires are particularly susceptible to high-frequency interference currents, battery voltage surges, and switching transients. These wires are generally long and are used to interconnect panels, relays, and subsystems throughout the train.

Control Measures:

- Minimize the length of train wires wherever possible
- Keep feeder and return conductors tightly bundled to reduce external magnetic field emissions
- Avoid routing sensitive cables in parallel with non-shielded train wires
- When parallel routing cannot be avoided (as is often the case), segregate cables using separate, well-earthed cable ducts or conduits
- Route non-shielded train wires through metallic ducts or conduits that are earthed at multiple locations to ensure effective EMI shielding
- Incorporate input filters in measurement and sensing circuits to suppress interference signals

6.6.6 Emission and Immunity of Purchased Parts

All externally procured components and systems must comply with relevant EMI/EMC standards. The supplier shall ensure that these parts have been tested and certified in accordance with applicable industry standards for emission limits and immunity performance.

7 Summary of Applicable Standards

7.1 EN 50121-1

EN 50121-1 is a product family standard which take precedence over generic standards. EN 50121-3-1 and EN 50121-3-2 are product standards.

7.1.1 Acceptance criteria for EMC tests

Apparatus shall not become dangerous or unsafe as a result of the application of the tests. A functional description and a definition of acceptance criteria shall be provided by the manufacturer and noted in the test report, based on the criteria A, B and C defined below.

Acceptance criteria A

The apparatus shall continue to operate as intended during and after the test. No degradation of performance or loss of function is permitted below the performance level specified by the manufacturer when the apparatus is used under normal conditions.

Acceptance criteria B

The apparatus shall continue to operate as intended after the test. Temporary degradation of performance is allowed during the test, but no loss of function or performance below the manufacturer's defined threshold is permitted. The operating state and stored data must remain unchanged.

Acceptance criteria C

Temporary loss of function is permitted, provided that the function is self-recoverable or can be restored by user operation of the controls. No permanent damage or safety impact shall occur.

Required acceptance criteria for the EMC immunity tests in this project are stated in table below.

Test	Acceptance Criteria
Supply under/over voltage	A
Supply interruption test	A
Polarity reversal test	No damages
Burst	A
ESD	B
Surge	B
Conducted RF immunity	A
Radiated RF immunity	A
Transient Electric Field Immunity test	A

Table 4: EN 50121 Acceptance Criteria for different tests

7.2 EN 50121-3-1 (IEC 62236-3-1)

This product standard for rolling stock specifies the electromagnetic emission and immunity limits necessary to ensure proper functioning of the system within its intended environment. No measurements are required at frequencies where no limits are defined.

7.2.1 Immunity Tests and Limits

No immunity tests are directly applied to the complete vehicle. However, the immunity tests and limits defined in Part 3-2 of this standard are selected with the understanding that the vehicle, as a system, should demonstrate immunity up to 20 V/m over the frequency range 150 kHz to 1 GHz.

It is assumed that, when assembled and integrated in accordance with a properly implemented EMC Plan one that follows the limits defined in Part 3-2 the complete vehicle will exhibit adequate electromagnetic immunity.

7.2.2 Emission Tests and Limits

Emission measurements must be performed under well-defined and reproducible conditions. As it is not possible to fully separate the effects of the railway infrastructure from the rolling stock under test, the test conditions and test site must be mutually agreed upon between the operator and the manufacturer in the contract, particularly for assessing compatibility with signaling and communication systems.

The impact of other parts of the railway system such as substations and signaling and external environmental factors (e.g., power lines, industrial areas, radio and TV transmitters) must be understood and considered in the evaluation.

7.2.3 Test Site Description

The test site must meet the following “free space” conditions, as far as practical, given the constraints of the railway environment:

- No trees, walls, bridges, tunnels, or vehicles should be located near the measurement point
 - Minimum separation distance:
 - 30 m for mainline vehicles
 - 10 m for urban vehicles
- When overhead lines are used, the measurement point shall be located at the midpoint between two support masts, on the side opposite the track being tested.
 - For third-rail systems, the antenna should be placed on the same side as the third rail (worst-case scenario).
- The overhead/third rail system should appear as an infinite line on both sides of the measurement point typically atleast 200 meters.
 -
- The test site should be free of overhead line discontinuities and infrastructure such as substations, transformers, neutral sections, and section insulators.
- The exact location and features of the test site, as well as the overhead/third rail layout, must be documented.

- Avoid proximity to external power lines (including buried cables) and substations.
-

If these ideal conditions cannot be met, ambient noise levels must be recorded before and after each emission measurement. Alternatively, a minimum of two ambient noise recordings one at the beginning and one at the end of the test series may be sufficient.

If ambient noise levels at any specific frequency (or frequency band) exceed the applicable limit minus 6 dB, those measurements may be disregarded. These frequencies shall be clearly noted in the test report.

7.2.4 Test Conditions

Hauled stock shall be tested in a stationary and energized condition, with auxiliary converters, battery chargers, and other onboard systems operating. The measurement antenna should be placed on the side of the vehicle opposite the equipment expected to generate the highest emissions within the frequency bands being measured.

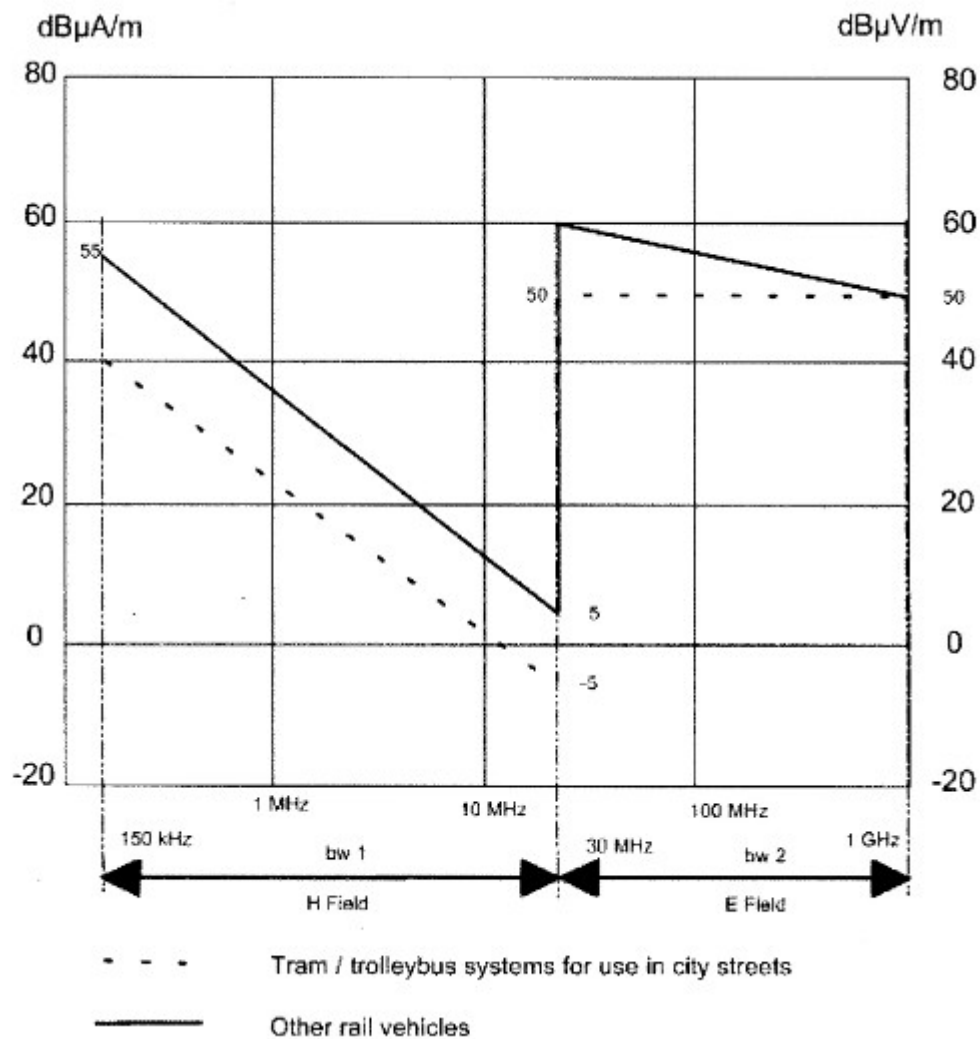
Traction stock shall be tested in two modes: stationary and slow moving.

- Stationary Test:
 - Auxiliary converters must be in operation.
 - Traction converters shall be powered (under voltage) but not actively driving.
 - The antenna shall be placed opposite the vehicle's centerline unless a different position is expected to yield higher emission readings.
- Slow Moving Test:
 - The vehicle should operate at a speed that prevents arcing or bouncing of the sliding contact, while still allowing for electrical braking.
 - Recommended speed ranges:
 - (20 ± 5) km/h for urban vehicles
 - (50 ± 10) km/h for mainline vehicles
 - The vehicle must pass the antenna while accelerating or decelerating with approximately one-third of its maximum tractive effort within the specified speed range.

7.2.5 Emission limits

Refer to the figure below for the emission limits applicable to the stationary test. The specified limits are defined as quasi-peak values, and the measurement bandwidths used correspond to those defined in EN 55016-1-1

Frequencies	Bandwidth
from 150 kHz to 30 MHz	9 kHz
above 30 MHz	120 kHz



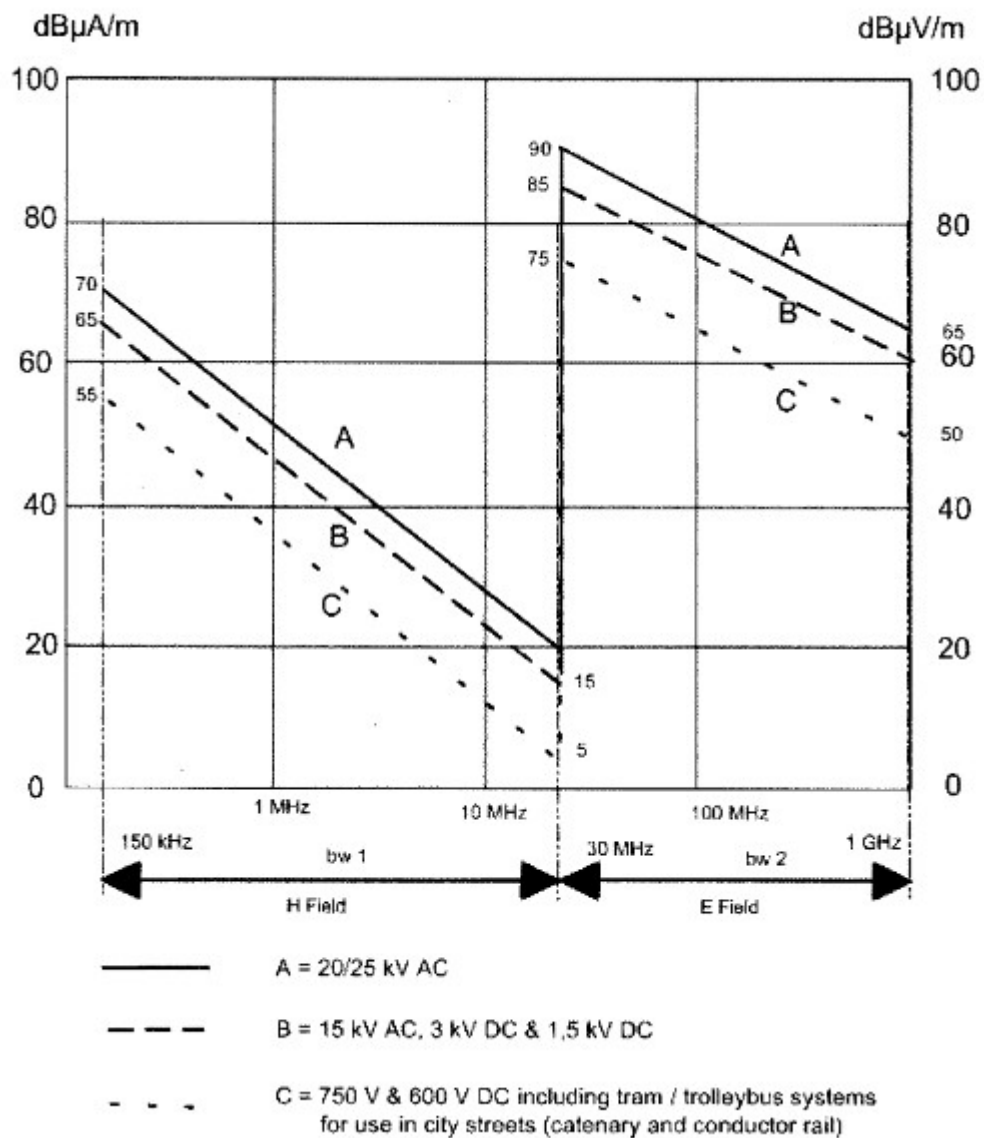
----- Trams/trolleybuses for use in city streets

———— Other rail vehicles

All values are measured at a distance of 10 m.

Figure 2: Limits for stationary test (QP, 10 m)

See below Figure for slow moving test limits.



A = 25 kV a.c.

B = 15 kV a.c., 3 kV d.c. & 1,5 kV d.c.

C = 750 V & 600 V d.c., including trams/trolleybuses for use in city streets

All values measured at a distance of 10 m in peak values.

Figure 3: Limits for slow moving test (Peak, 10 m)

7.3 EN 50121-3-2 (IEC62236-3-2)

7.3.1 Emission test

7.3.1.1 Conducted emission test

Basic Standard: EN 55011 (CISPR 11)

Requirement: EN50121-3-2 (IEC 62236-3-2) table 1&2

Port	Frequency range	Limits dB μ V/m quasi-peak	Test set-up	Remarks
Battery power supply			EN 55016-2-1	Battery power supply to I/O-ports (groups) included
AC power input ports (rated voltage $\leq$ 400Vrms)	150kHz – 500kHz	99dB μ V		
	500kHz – 30MHz	93dB μ V		
Battery-referenced port (All electronics control unit)	150kHz – 500kHz	99dB μ V	EN 55016-2-1	For definition of electronic supply see port 16, figure A.5 in EN50121-3-2
	500kHz – 30MHz	93dB μ V		
AC power outlet port for public use	50 Hz to 2 KHz	THD<8%	EN61000-4-30	230 V AC Power outlet for public use. In High speed, harmonic content will be measured on output of Auxiliary converter, 415 V, 3 phase AC, as it is a source for 230 V or 110 V AC.
Battery referenced I/O				No test required
Signal & communication, process measurement and control ports				No test required

Table 5: Conducted emission tests

The requirements of EN 55016-2-1 shall be fulfilled, with the following clarifications and additions:

- The specified emission limits do not apply to transient emissions. This includes, for example:
 - Starting or stopping the test object
 - Continuous switching of digital input/output ports

- Continuous switching of relays
- Any power supply operating at vehicle battery voltage shall be assumed to use non-shielded cabling for the purposes of the test setup and analysis.
- Only the quasi-peak test method needs to be applied, using the specified quasi-peak limits defined in the standard. Other detection methods (e.g., peak, average) are not required for compliance evaluation.

7.3.2 Immunity test

7.3.2.1 Fast transient burst immunity test

Basic standard: IEC 61000-4-4

Performance criteria: A

Requirements: EN50121-3-2 (IEC62236-3-2) table 3.2 / 4.2

Port	Test specification	Test set-up	Remarks
Battery referenced ports AC power input ports (rated voltage ≤ 400 V)	5/50 ns (Tr/Th) 5 kHz (rep. Freq.) Common mode: 2 kV Line to earth: 2 kV	IEC 61000-4-4. Direct coupling. Positive and negative polarity	Battery referenced I/O ports included
Signal & communication, process measurement and control ports	5/50 ns (Tr/Th) 5 kHz (rep. Freq.) Common mode: 2 kV Line to earth: 2 kV	IEC 61000-4-4. Direct coupling. Positive and negative polarity	Unshielded lines
	5/50 ns (Tr/Th) 5 kHz (rep. Freq.) 2 kV	IEC 61000-4-4. Capacitive coupling clamp. Positive and negative polarity	Shielded lines

Table 6: Fast transient burst immunity tests

The requirements of IEC 61000-4-4 shall be fulfilled with the following clarifications and additions:

- The length of the signal and power lines between the coupling/decoupling network (CDN) and the equipment under test (EUT) shall not exceed 1 meter.
- The duration of the test shall be a minimum of one minute for each polarity of the applied disturbance.

7.3.2.2 Surges immunity test

Basic standard: IEC 61000-4-5

Performance criteria: B

Requirements: EN50121-3-2 (IEC62236-3-2) table 3.3

Port	Test specification	Test set-up	Remarks
Battery referenced ports AC power input ports (rated voltage ≤ 400 V)	1.2/50 μ s (Tr/Th) Line to earth: 2 kV (open circuit) Differential Mode: 1 kV (open circuit)	IEC 61000-4-5 Figure 10 R=42 Ω , C=0.5 μ F	Battery referenced I/O ports included Test applied to unshielded lines only

Table 7: Surges immunity tests

The requirements of IEC 61000-4-5 shall be fulfilled with the following clarifications and additions:

- The length of the signal and power lines between the equipment under test (EUT) and the coupling/decoupling network (CDN) shall be 2 meters or shorter.
- A minimum of five positive and five negative surges shall be applied at each EUT port.
- The same EUT and EUT port shall be used for both positive and negative polarity surge testing to ensure consistency.
- The interval between successive surge applications shall be not less than 10 seconds and not more than one minute.
- Surges shall be applied under both conditions:
 - With the control system supply voltage present
 - With the control system supply voltage absent

7.3.2.3 Conducted disturbances induced by RF fields – immunity test

Basic standard: IEC 61000-4-6

Performance criteria: A

Requirements: EN50121-3-2 table 3.1/4.1

Port	Test specification	Test set-up	Remarks
Battery referenced ports AC power input ports (rated voltage ≤ 400 V) Signal & communication, process measurement and control ports	0.15-80 MHz 10 Vrms 80% AM (1kHz) 150 Ω (source impedance)	IEC 61000-4-6	The test level specified is the rms value of the unmodulated carrier.

Table 8: Conducted disturbances induced by RF fields – immunity tests

The requirements of IEC 61000-4-6 shall be fulfilled with the following clarifications and additions:

- The clamp injection method shall be used only when coupling through coupling/decoupling

networks (CDNs) is not feasible or appropriate. For coupling to supply lines, the use of CDNs is mandatory.

- The frequency sweep rate during testing shall not exceed 1.5×10^{-3} decades per second.

7.3.2.4 Radiated radio-frequency electromagnetic HF-fields immunity test

Basic standard: IEC 61000-4-3

Performance criteria: A

Requirements: EN50121-3-2 (IEC62236-3-2) table 5

Port	Test specification	Test set-up	Remark
Enclosure	80-800 MHz 80 % AM (1kHz) 20 V/m All installation locations	IEC 61000-4-3	See note [1]
	800 Mhz to 1000 Mhz 20 V/m RMS 80% AM (1kHz) Unmodulated carrier	IEC 61000-4-3	See note [1]
	1400 Mhz to 2000 Mhz 10 V/m RMS 80% AM (1kHz) Unmodulated carrier	IEC 61000-4-3	See note [1]
	2000 Mhz to 2700 Mhz 5 V/m RMS 80% AM (1kHz) Unmodulated carrier	IEC 61000-4-3	See note [1]
	5100 Mhz to 6000 Mhz 3 V/m RMS 80% AM (1kHz) Unmodulated carrier	IEC 61000-4-3	See note [1]

Table 9: Radiated radio-frequency electromagnetic fields immunity tests

Note[1] : The limit applies to equipment mounted in the passenger compartments, drivers cab or external to the rolling stock (roof, underframe). For equipment mounted in all other areas a severity level of 10 V/m may be used.

7.3.2.5 Electrostatic discharge immunity test

Basic standard: IEC 61000-4-2 [5]

Performance criteria: B

Requirements: EN50121-3-2 table 5.3

Port	Test specification	Test set-up	Remarks
Enclosure	Contact discharge: +/-6 kV	IEC 61000-4-2 Figure 4 or 5	See basic standard for applicability of contact and/or air discharge test.

	Air discharge: +/-8 kV	Positive and negative polarity	Only applicable to equipment available to operation staff and passenger
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Table 10: Electrostatic discharge immunity tests

The requirements of IEC 61000-4-2 shall be fulfilled with the following clarifications and additions:

- Electrostatic discharges (ESD) shall be applied only to those points and surfaces of the equipment under test (EUT) that are normally accessible to passengers or operating staff
- If the equipment is enclosed within an earthed panel, this test is not applicable
- The test voltage shall be progressively increased from the minimum test level up to the final test level specified in the applicable table above

7.3.3 Supply Over Voltage Test

Basic standard: IEC60571 clause 12.2.7 is to be applied

Performance criteria: See remarks

Port	Test specification	Test set-up	Remark
Battery-referenced ports	1.4 x U _N V (min. over voltage) 0.1s (max. rise time d) 1s (min. duration D) 1 Ω	IEC60571 12.2.7	EN 50155 5.1.1.1 Performance Criteria A

Table 11: Supply under/over voltage tests

The requirements of IEC 60571 shall be fulfilled with the following clarifications and additions:

- The test waveform shall have the same polarity as the system supply voltage. The system supply voltage shall be present both before and after the injection of the test waveform.
- The applied voltage shall be measured with respect to the control system supply return potential.

7.3.4 Supply Interruption Test

Basic standard: IEC 60571 clause 5.1.1.3 and 12.2.3 is to be applied

Performance criteria: A

Port	Test specification	Test set-up	Remark
Battery-referenced ports, power supply	Class S2 10ms interruption	IEC 60571 clause 5.1.1.3 and clause 12.2.2	

7.3.5 Supply voltage variation test

Basic standard: IEC 60571 clause 12.2.3 is to be applied

Performance criteria: A

Port	Test specification	Test set-up	Remark
Battery-referenced ports, power supply	0.7xUn to 1.25xUn	IEC 60571 clause 12.2.3	

Table 12: Supply voltage variation test

7.4 EMC Test According to IEC 61133

This test will be conducted as part of vehicle level testing, refer vehicle test plan for more details.

8 EMI/EMC Tests on Various Equipments

8.1 EMI/EMC Tests on TCMS and Other Control Electronics

This covers CCU, MCU, PCU, LTC, ECN switch, ETB switch Auxiliary converter control unit, Battery charger Unit, PIS, Infotainment, CCTV and DDU. As a part of EMI/EMC test, following tests are done:

Port	Test Name	Test set-up / Standard	Test Specification	Performance Criteria / Limits	Remarks
Battery Reference port	Supply Voltage variation test	IEC 60571, Clause 12.2.3	0.7xUn to 1.25xUn	A	
Battery Reference port	Supply Voltage interruption test	IEC 60571 clause 5.1.1.3 and 12.2.3	Class S2 10ms interruption	A	
Battery Reference port	Supply Over voltage test	IEC 60571, Clause 12.2.7	1.4 x U _N V (min. over voltage) 0.1s (max. rise time d) 1s (min. duration D) 1 Ω	A	
Battery Reference port	Fast transient burst immunity test	IEC 61000-4-4 figure 8. Direct coupling. Positive and negative polarity	5/50 ns (Tr/Th) 5 kHz (rep. Freq.) Common mode: 2 kV Line to earth: 2 kV	A	
Battery Reference port	Surge immunity test	IEC 61000-4-5 Figure 10 R=42 Ω , C=0.5 μ F IEC 61000-4-5 Figure 11 R=42 Ω , C=0.5 μ F	1.2/50 μ s (Tr/Th) Line to earth: 2 kV (open circuit) Differential Mode: Line to Line 1 kV (open circuit)	B	
Battery Reference port	Radio Frequency conducted immunity test	IEC 62236-3-2, Table 3 and IEC 61000-4-6	0.15-80 MHz 10 Vrms 80% AM (1kHz) 150 Ω (source	A	

Port	Test Name	Test set-up / Standard	Test Specification	Performance Criteria / Limits	Remarks
			impedance) IEC 62236-3-2, Table 3 and IEC 61000-4-6		
Battery Reference port	Conducted emission test	EN 55011, IEC 62236-3-2, table 2	150kHz – 500kHz	99dB μ V quasi-peak	
			500kHz – 30MHz	93dB μ V quasi-peak	
Signal and communication port	Fast transient burst immunity test	IEC 61000-4-4 figure 8. Capacitive coupling. Positive and negative polarity	5/50 ns (Tr/Th) 5 kHz (rep. Freq.) Common mode: 2 kV Line to earth: 2 kV	A	
Signal and communication port	Radio Frequency conducted immunity test	IEC 62236-3-2, Table 4 and IEC 61000-4-6	0.15-80 MHz 10 Vrms 80% AM (1kHz) 150 Ω (source impedance) IEC 62236-3-2, Table 4 and IEC 61000-4-6	A	
Enclosure Port	Radio frequency radiated immunity test	IEC 61000-4-3 IEC 62236-3-2, table 5	80-800 MHz 80 % AM (1kHz) 20 V/m All installation locations in passenger area	A	For the control electronics not mounted in passenger area, the severity level shall be taken as 10V/m
Enclosure Port	Electrostatic discharge test	IEC 61000-4-2 Figure 4 or 5 Positive and negative	Contact discharge: +/-6 kV Air discharge: +/-8 kV	B	This test is to be done only on that control electronics

Port	Test Name	Test set-up / Standard	Test Specification	Performance Criteria / Limits	Remarks
		polarity			which are directly accessible to Users or passenger. This is only done on DDU, CCMS.

Table 13: EMI/EMC tests on Control Computer

9 Cable Classification and Segregation

Cables are a critical part of any system, responsible for routing signals and power throughout the train for various control and operational purposes. Since cables carry a wide range of signal types, improper handling or installation can result in undesired signal coupling, which may distort original signals due to various forms of electromagnetic interference (EMI).

The following types of coupling mechanisms can occur between cables:

a) Capacitive Coupling: The strength of capacitive coupling depends on

- The length over which cables are laid in parallel
- The physical distance between adjacent cables
- The proximity of the cables to the vehicle body (earth)

b) Inductive Coupling: The strength of inductive coupling is influenced by

- The conductor loop area with respect to the vehicle body. If cables are routed close to the grounded body of the vehicle, the loop area is minimized, thereby reducing inductive coupling
- The distance between cables. Greater spacing reduces mutual inductance and, consequently, the coupling effect

In practice, it is not always feasible to maintain ideal separation distances between all cables due to physical and design constraints. To address this challenge, cables are classified into categories based on:

- The type of signal they carry
- The level of electromagnetic interference (EMI) they may generate
- Their susceptibility to external EMI

To mitigate interference, minimum separation distances between these cable categories are maintained as far as practically possible, thereby improving signal integrity and ensuring overall system reliability.

The following section defines the cable categories used in the system.

Cable Category	Cable Type
A	• Power supply 1: Pantograph / Current collector cables supplying traction, heating, auxiliary power supply converters • Power supply 2: Motor cables, braking resistor cables, cables to line filters(on inverter side), auxiliary equipment supply cables, combustion motor starter cables etc.
B	• Battery cables, binary control cables etc.
C	• Cables for signal transmitters, antenna cables, loudspeakers cables, data bus cables etc.

Table 14: Cable Categories

Cable categories	Separation distance
A and B	100mm
A and C	200mm
B and C	100mm

Table 15: Cable segregation between different categories

Note: The above separation guidelines apply when cables are laid in open air. However, if a metallic partition is incorporated into the cable tray design to separate different types of cables, it functions as an effective electromagnetic shield. In such cases, the required separation distances between cable categories can be reduced, as the metallic partition significantly minimizes electromagnetic coupling and interference between adjacent cables.

9.1 Cable Laying in Cable Duct

To ensure electromagnetic compatibility (EMC) while laying cables of various categories, the following precautions shall be observed:

- Cables shall be routed in metallic cable ducts that are earthed at regular intervals, or at a minimum, at both ends, to reduce interference and crosstalk.
- The metallic duct shall be continuous and should enclose the cables as fully as possible to improve shielding effectiveness.
- Cables of different categories must be laid separately, maintaining the specified minimum separation distances to avoid mutual interference.
- Outgoing and return conductors, especially for power circuits, shall be laid together to minimize electromagnetic emissions.
- Cables shall be installed as close as possible to the vehicle body (earth) preferably in closed metallic ducts or pipes which must be electrically bonded to the vehicle structure to maximize shielding and minimize loop area.
- When maintaining the required separation between cable categories is not feasible particularly for data cables pipes, closed metal sheets, or metallic ducts shall be used for segregation. These physical barriers shall be bonded to the vehicle body at both ends, and preferably at multiple points along their length.
- Data and communication cables must always be shielded to prevent signal degradation due to electromagnetic interference.
- No minimum clearance is required when cables from different categories cross at right angles, as this geometry minimizes coupling.
- In Trainsets:
 - Category A cables are routed in the power tray
 - Category B and C cables are routed in the control tray
 - Within the control tray, a partition and an air gap of 50 mm are maintained between Category B and Category C cables, as illustrated in the figure below

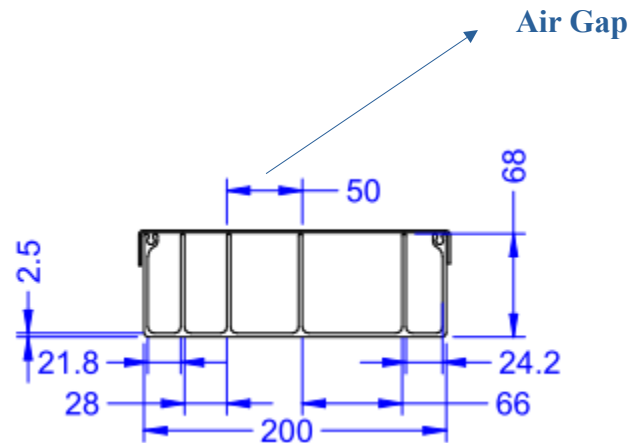


Figure 4: Segregation of category B and Category C cables and its laying in trays

10 Cable Shielding

Proper cable shielding is essential to protect sensitive signals from electric, magnetic, and electromagnetic interference. The following general considerations shall be taken into account when implementing cable shielding:

- **Shielding Against Electric Fields :** Alternating electric fields induce displacement currents on the metallic shield, which create an equipotential surface around the conductor. However, the effectiveness of the shield decreases with increasing frequency, as the resistance of the shield rises, limiting its shielding performance.

To ensure effective shielding:

- The shield must be connected at both ends using a low-resistance conductor or copper plate
- It must be ensured that the earth potential across the vehicle rake is equal; otherwise, multiple grounding points may create loop currents, distorting signal quality
- For the purpose of this design, it is assumed that vehicle earth potential is consistent along the entire trainset
- **Shielding Against Magnetic Fields :** Alternating electric fields (particularly from fast-varying signals) produce magnetic fields that can interfere with nearby data and communication lines if not properly shielded.
 - Metallic shields help block magnetic fields by allowing eddy currents to be induced in the shield, which in turn cancel out the magnetic field
 - The magnitude of eddy currents increases with the frequency of the magnetic field, enhancing the shielding effect at higher frequencies
 - Shielding must be grounded at both ends for effective performance
 - The shield must completely enclose the cable any gaps or openings act as apertures

that allow magnetic fields to penetrate

- Shielding Against Electromagnetic Fields : Electromagnetic fields are a combination of electric and magnetic fields. Therefore, the shielding principles for both electric and magnetic fields must be applied simultaneously to achieve effective protection.

10.1 Shielding of Data and Communication Cable

The following standard practices shall be observed when shielding data and communication cables:

- Shields of signal and data cables shall be earthed at both ends
- Shield connections should make full-surface contact with the shielding surfaces of connected devices or components to ensure low-impedance grounding
- Cable shields must be connected immediately upon entry into the housing to prevent interference currents from propagating into the enclosure
- Shielding should fully surround the plug connector, ensuring 360-degree contact between the shield and the connector housing
- If minimum separation distances (as per defined cable categories) cannot be maintained from high-interference conductors and if data cables are routed in parallel over distances longer than 1 meter, the following precautions shall be taken:
 - The affected data cables must be routed inside metallic conduits or separated using barriers or closed cable ducts
 - These protective enclosures must be conductively bonded to vehicle earth at both ends



Figure 5: Shielding clamp used for shield grounding

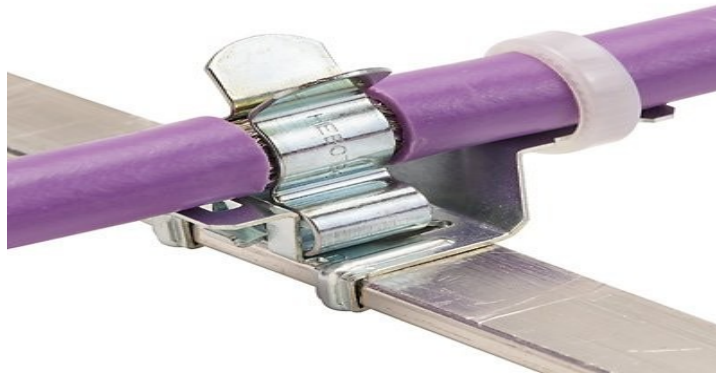


Figure 6: Shielding clamp with cable shield connection

The figure above illustrates the connection of a cable shield to a 360-degree shield clamp, which represents the best practice for shield termination. In this configuration, the cable shield is completely enclosed by the clamp, ensuring full-surface contact and minimizing impedance at the grounding point.

The shield clamp is mounted directly onto a metal plate, preferably made of copper or stainless steel, due to their excellent electrical conductivity and corrosion resistance. This metal plate is then directly bonded to the vehicle earth, ensuring an effective and low-resistance path for the dissipation of interference currents.

This method provides optimal shielding performance against both conducted and radiated electromagnetic interference, protecting sensitive onboard systems from disturbances.



Figure 7: Cable shield connection to connector for shield grounding

The figure above illustrates an alternate method of cable shield connection. While this method is acceptable, it is not as effective as the 360-degree shield clamp connection described earlier.

In this configuration, the cable shield is terminated onto the metallic body of the connector, which is then electrically bonded to the earthed metallic enclosure of the control unit. This provides a grounding path for interference currents via the connector and the equipment housing.

Although this method offers basic shielding effectiveness, it may result in higher impedance at the grounding interface and less uniform current dissipation, especially at higher frequencies. Therefore, it is considered a secondary option when 360-degree shield termination is not feasible.

10.2 Shielding of Power Cable

As is well known, cable shielding plays a crucial role in reducing emitted electromagnetic interference (EMI). Therefore, all power cables that carry pulsating voltages, high currents, or high-frequency noise originating from main power components must be either:

- Screened, or
- Routed through metallic conduits, preferably made of stainless steel,

and must be earthed at regular intervals to ensure effective attenuation of radiated emissions.

To further minimize electromagnetic emissions, power and return cables should always be routed close to each other. This practice reduces the loop area, thereby limiting the associated magnetic field radiation.

For grounding, cable trays should preferably be connected to the vehicle earth using copper braided wire with a cross-sectional area of 6 to 10 mm². To maintain a low-impedance grounding path, the length of the earth wire should be limited to 300 mm to 500 mm.

10.3 Shielding of Ethernet Cable

Proper shielding and grounding of Ethernet cables is essential to maintain data integrity and minimize susceptibility to electromagnetic interference (EMI), especially in railway environments where high-power equipment and switching transients are common.

Precautions for Ethernet Cable Laying and Shield Connection:

- The shield of each Ethernet cable shall be connected at both ends to ensure continuous shielding and to reduce EMI susceptibility.
- The shield shall also be bonded at every inter-vehicular coupler using a low-impedance connection to the vehicle earth, thereby maintaining shielding continuity across coupled vehicles.
- Ethernet cables shall be routed in metallic conduits or trays along their entire length to provide both mechanical protection and electromagnetic shielding.
- The metallic conduits or trays shall be earthed to the vehicle body at multiple locations to ensure low-impedance grounding and effective EMI suppression.
- Screen stripping at the connector end shall be minimized to reduce the exposure of inner conductors and to maintain the shielding effectiveness of the cable assembly.

10.4 General Requirements for Shield Connection

Proper shield connection practices are critical to maintaining effective electromagnetic compatibility (EMC) and ensuring the long-term reliability of onboard systems, particularly in vibration-prone environments such as railway vehicles.

Precautions for Shield Connection:

- All earthing and shield connections must be low impedance and resistant to vibration to ensure reliable long-term performance
- The shield shall be connected at both ends, and continuity must be maintained throughout the entire cable length. Any unshielded or exposed segments at connectors or terminations shall be kept as short as possible to minimize EMI leakage
- Contact surfaces used for shield connections must be free from corrosion, oxidation, paint, or dirt. The connection area must be cleaned and prepared properly before establishing the shield bond
- Bolted connections shall be mechanically secured, using methods such as lock washers, spring washers, or thread-locking compounds, to prevent loosening due to vibration and mechanical stress

11 Earthing plan

Refer Earthing plan document (CD-3931)

12 Mechanical Design Considerations for EMI/EMC

To minimize the impact of electromagnetic interference (EMI) and ensure electromagnetic compatibility (EMC), the following precautions shall be incorporated into the mechanical design of the train's electrical and electronic systems:

- All sensitive control electronics and computers shall be enclosed in mild steel (MS) / Other suitable metallic housings to provide effective electromagnetic shielding
- Mechanical enclosures for computers and electronics shall include a dedicated earth stud to ensure reliable grounding; the earth connection length shall be kept as short as possible to minimize impedance
- Non-magnetic cable trays or conduits shall be used for cable routing to prevent unintended magnetic coupling
- All segments of the cable tray system shall be electrically bonded to ensure continuous grounding throughout the tray
- The height of the cable trays shall be selected such that cables remain below the tray edge, preventing mechanical stress and exposure
- Cable trays and conduits shall be earthed at regular intervals to maintain shielding effectiveness and low-impedance grounding
- Electrical panels shall be grounded using cables with a minimum cross-sectional area of 35 sq.mm
- Control cubicles shall be grounded using cables with a cross-sectional area between 2.5 sq.mm and 4 sq.mm
- The length of the earth cable connecting enclosures or trays to the vehicle earth shall be limited to 300 mm to 500 mm to reduce ground loop impedance and maintain effective EMI suppression

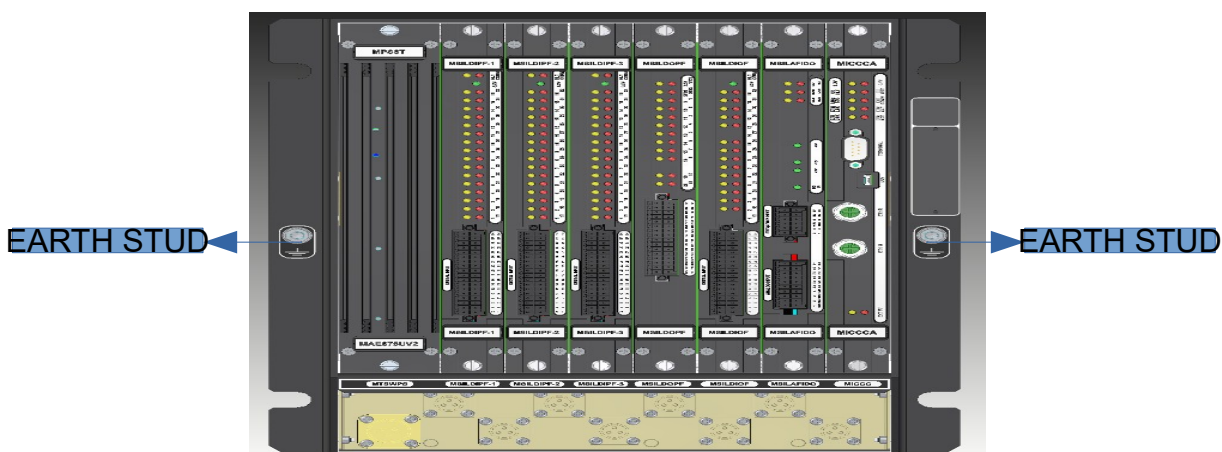


Figure 8: Control unit

NOTE: This picture is only for illustration purposes, final Control unit may vary.

13 Filter

All housings for sensitive control electronics wherever necessary shall be equipped with both common-mode and differential-mode filters on the 110 V DC power lines. The filter body shall be properly earthed to ensure effective operation. These filters serve to reduce or eliminate conducted noise.

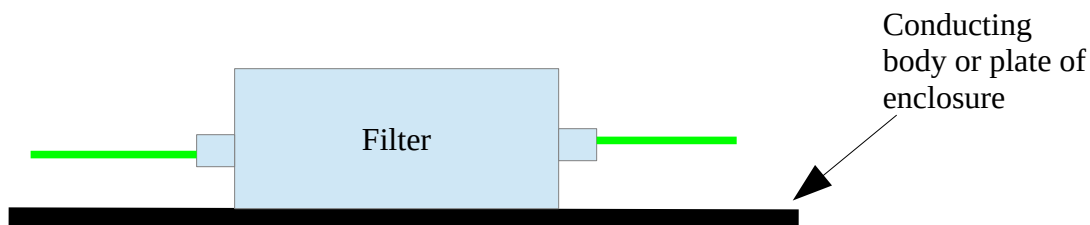


Figure 9: Correct mounting of filter

ATTACHMENT – 2

**Reply sheet to NHSRCL's Feedback on EMC
control plan and Vehicle earthing concept -
FPIIC/TD/232, Rev.00**

SUBMISSION REVIEW SHEET

Design, Manufacture and Commissioning of Train-B28

Submission Document ID	B28/VR.09.00.00/P/B037/A0	Submission Date	03.07.2025 (BEML Email)
Submission Document No.	FPIIC/TD/232	Submission Revision No.	Rev. 0
Subject/Title	EMC Control plan and Vehicle Earthing Concept	Type of Document	PDR (Preliminary Design)
Status:	☐ No-Objection	☐ No-Objection with comments	☒ Objection

SN	Reference	Observations
1.	Attachment-1 CD- 3796 Rev-0 Pg 7/16, 1.1 Objective	Please include in the objective, that the system designed is immune to any EMC related noises from any external environment. Medha Reply: Updated
2.	Attachment-1 CD- 3796 Rev-0 Pg 7/16, 1.2 scope	It is not clear, the EMC Control plan is meant for whole Rolling Stock, whereas the scope defined Medha supplied equipment and infrastructure, but not the other systems installed on the Rolling Stock such as HVAC, Doors, Brakes, Pantry equipment, Measuring Equipment, etc. Supplier shall reconcile the EMC concepts for the whole Rolling Stock. Medha Reply: Updated
3.	Attachment-1 CD- 3796 Rev-0 Pg 7/16, 1.2 scope	a. The scope shall be included the following: i. Organization & role – The role of team members for incorporating EMP plan. - ii. Design rules for EMC iii. Analysis of EMI impact iv. Safety and Non safety related systems v. Environmental EMC vi. EMC control & Tests vii. Submission of documents related to EMC. Medha Reply- Updated in section 1.2 b. However, Medha will not be responsible for the performance or compatibility of foreign equipment, nor for general conducted or radiated emissions already present in the external railway environment. - It is not clear about the compatibility of foreign equipment with whom. The supplier shall clarify this in the next revision. Medha reply: It means that there are some items which are outside the scope of Medhat/BEML. Respective Vendor will take all the responsibility to meet EMC requirement, however at vehicle level we will co-ordinate to integrate and take EMC measures.
4.	Attachment-1 CD- 3796 Rev-0 1.4.2 Other Standards	The following standards shall be added: • EN 50343: specifies requirements for the installation of cabling on railway vehicles and within electrical enclosures on railway vehicles. • Although the objective covers the human interference compatibility, no standard has been referred to. Therefore, EN 50500: Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure.

SUBMISSION REVIEW SHEET

Design, Manufacture and Commissioning of Train-B28

Submission Document ID	B28/VR.09.00.00/P/B037/A0	Submission Date	03.07.2025 (BEML Email)
Submission Document No.	FPIIC/TD/232	Submission Revision No.	Rev. 0
Subject/Title	EMC Control plan and Vehicle Earthing Concept	Type of Document	PDR (Preliminary Design)
Status:	☐ No-Objection	☐ No-Objection with comments	☒ Objection

SN	Reference	Observations
		Medha Reply- Updated
5.	Attachment-1 CD- 3796 Rev-0 Sec. 2.1.3	Demonstration of compatibility for human exposure shall also be included. Medha Reply: Updated
6.	Attachment-1 CD- 3796 Rev-0 2.2 Synthesis Phase	- Synthesis shall be done whole rolling stock including all on-board systems - In Sec. 2.2.3 Particular EMC Measures – Power supply system shall also be studied w.r.t. 25 kV roof-line and OHE. Medha Reply- Updated
7.	Attachment-1 CD- 3796 Rev-0 4 Various Equipment and EMC Measures	The list shall be updated with HVAC, Plug Doors, Fire Doors, IC Doors, Measuring Equipment, Condition Based Monitoring system, Coupler nose mechanism. Medha Reply-Updated
8.	Attachment-1 CD- 3796 Rev-0 6 Sources of EMI	There shall be some pictorial representation for better understanding of the EMC mitigation plan in next submission. Medha Reply: These are generic description. Figures are already provided wherever needed.
9.	Attachment-1 CD- 3796 Rev-0 6.2.2 Contact Bounce from a Pantograph	- In Interference Pathways, HT room is not understood. The supplier shall mention its location in B28 trains. - DC link capacitor shall be designed so that uninterrupted supply to be maintained to Inverter of Traction system in case of panto bounce. Medha Reply- Updated
10.	Attachment-1 CD- 3796 Rev-0 6.3 Interference Originating in Train-Borne Equipment	- The grouping is based on the characteristics and EMI behavior of the source of EMI. The supplier shall furnish the characteristics and EMI behavior in next submission. 6.3.1 (g) Switched Mode Power Supplies (SMPS) – Mention the use of SMPS in B28 trains. Medhat Reply- SMPS is used in every computer i.e., TCMS, LTC computer, PIS, CCTV to derive low voltage source from 110 V DC. Purpose of SMPS is given in section 6.3.8 6.3.1 (c) is for lightning system and 6.3.4 Lighting Systems- Both are different. The supplier shall correct and also include VCB as it involves switching.

SUBMISSION REVIEW SHEET

Design, Manufacture and Commissioning of Train-B28

Submission Document ID	B28/VR.09.00.00/P/B037/A0	Submission Date	03.07.2025 (BEML Email)
Submission Document No.	FPIIC/TD/232	Submission Revision No.	Rev. 0
Subject/Title	EMC Control plan and Vehicle Earthing Concept	Type of Document	PDR (Preliminary Design)
Status:	☐ No-Objection	☐ No-Objection with comments	☒ Objection

SN	Reference	Observations
		Medhat Reply- Yes, both are different system. VCB is not required to be included as VCB is just an ON/OFF device and do not produce any EMI. 6.3.6 Relays – Mention 110V, 1-Φ AC & 230V, 1-Φ AC also along with 415V AC & 110V DC. Medhat Reply—All Relay has same characteristics irrespective of power source. Also, we are not using any relay on AC source. So, all are DC relays. - For reduction of EMC/EMI effect, the LTC control scheme shall have interlacing of firing angles IGBTs. The supplier shall furnish the interlacing scheme. Medha Reply- Yes interlacing is used to cancel harmonic on primary side. Interlacing is done based on number of active LTC and angle of firing angle of IGBT. Same is updated in section 6.3.7
11.	Attachment-1 CD- 3796 Rev-0 6.6 Interference Pathways	6.6.1 HV Cabling Terminated Inside High-Tension (HT) Cabinets- The concept of HVDC cabling is not understood in respect to B28 trains. The supplier shall submit the justification. Medha Reply- Section updated
12.	Attachment-1 CD- 3796 Rev-0 8.1 EMI/EMC Tests on TCMS and Other Control Electronics	Tests related to Radiated emissions conforming to EN50121-3-2:2006 / EN55011:2009 to be added. Medha Reply- Radiated emission at equipment level is removed from EN50121-3-2, 2016 version. Now radiated emission test is done vehicle level to meet overall limit as per EN50121-3-1.
13.	Attachment-1 CD- 3796 Rev-0 9 Cable Classification and Segregation	- In general EMC compliance shall be followed using the following standards too, Supplier shall assess the applicability for the Train and include the compliance accordingly: a) EN 50122- Railway applications - Fixed installations - Electrical safety, earthing and the return circuit b) EN 61000-1-1: Electromagnetic compatibility (EMC) - Part 1: General - Section 1: Application and interpretation of fundamental definitions and terms c) EN 61000-5-2: Installation and mitigation guidelines - Earthing and cabling d) EN 60204: Safety of machinery - Electrical equipment of machines e) EN 50153: Railway applications. Rolling stock. Protective provisions relating to electrical hazards Medha Reply- updated in section 1.4.2 - The definition reg. Bonding, Grounding, System grounding & Protective grounding shall be added.

SUBMISSION REVIEW SHEET

Design, Manufacture and Commissioning of Train-B28

Submission Document ID	B28/VR.09.00.00/P/B037/A0	Submission Date	03.07.2025 (BEML Email)
Submission Document No.	FPIIC/TD/232	Submission Revision No.	Rev. 0
Subject/Title	EMC Control plan and Vehicle Earthing Concept	Type of Document	PDR (Preliminary Design)
Status:	☐ No-Objection	☐ No-Objection with comments	☒ Objection

SN	Reference	Observations
		Medha Reply- All these details are already provided in Earthing plan. • Details of cables used for earthing system shall be submitted. Medha Reply- This detail will be submitted in DDR • Details of earth mesh/pads used for termination of cables shall be submitted. Medha Reply- This detail will be submitted in DDR
14.	Others	• Clause by clause compliance shall be submitted. Medha Reply- There is no specific clause for this. CWC for subsystem wise is already covered in respective document • The document shall have basics of EMC/EMI with inter system and intra system. Medhat Reply- Section 2, 4, 5to 11 explain basis only for EMI and EMC.

Notes:

1. No-Objection: Submission does not contain any non-compliance to the contract. The Contractor can proceed to the next stage.
2. No-Objection with comments: Submission contains minor non-compliance to contract, discrepancies, omissions or errors which are not of a fundamental nature. The Contractor can proceed to the next stage. Revised submission to be made by the Contractor complying with the comments within 14 days or other date as specified.
3. Objection: Submission contains major non-compliance to contract, discrepancies, omissions or errors which are of a fundamental nature. The Contractor cannot proceed to next stage. Revised submission to be made by the Contractor, complying to the comments within 14 days or other date as specified.

ATTACHMENT – 3

**Reply sheet to DB's Feedback on EMC control
plan and Vehicle earthing concept -
FPIIC/TD/232, Rev.00**



BEML - High Speed Rail

Design Review Comment Sheet

Document No.	FPIIC/TD/232	BEML Submission Date:	03.07.2025
Document Name	EMI-EMC Control Plan and Vehicle Earthing Concept	Revision:	00
Document Review Status:	☐ Level A ☐ Level B ☒ Level C ☐ Level D	Date of Review:	18.07.2025

SN.	Section Ref No.	DB E&C Comments	Review Status	BEML/Medha/EC-E Response	Sections Modified													
1	5.2 Page 22/61	EMC Management Organisation in each of the Agencies involved in manufacturing of the Train need to be defined, with responsibility demarcations. Hierarchical Chart (e.g. in BEML, Medha) may be enclosed showing persons responsible for EMC Management at different levels and for different activities. E.g.: design stage, manufacturing stage, final testing stage.	C	Details will be provided during DDR														
2	-	RF radiated emission for stationary vehicles are suggested to be maintained as per the following limits: <i>*: Straight line dB/log(f) scale</i> <table><tr><th>Field</th><th>Frequency, MHz</th><th>Radiated Field Limits at 10m(*)</th></tr><tr><td rowspan="2">Magnetic Field (dB/μA/m)</td><td>0.15</td><td>55</td></tr><tr><td>30</td><td>5</td></tr><tr><td rowspan="2">Electric Field dBm V/m</td><td>30</td><td>60</td></tr><tr><td>1000</td><td>50</td></tr></table>	Field	Frequency, MHz	Radiated Field Limits at 10m(*)	Magnetic Field (dB/μA/m)	0.15	55	30	5	Electric Field dBm V/m	30	60	1000	50	C	As per EN50121-3-1, limits are variable between 150 kHz to 30 MHz and from 30 MHz to 1 GHz. Representation in tabular format may not be correct representation. Same is represented in figure 2 and figure 3.	
Field	Frequency, MHz	Radiated Field Limits at 10m(*)																
Magnetic Field (dB/μA/m)	0.15	55																
	30	5																
Electric Field dBm V/m	30	60																
	1000	50																

DOCUMENT REVIEW SHEET	
Document No: FPIIC/TD/232	BEML Submission Date: 03.07.2025
	DB Review Date: 18.07.2025



BEML - High Speed Rail

SN.	Section Ref No.	DB E&C Comments			Review Status	BEML/Medha/EC-E Response		Sections Modified
3	-	RF radiated emission for slow moving vehicles may be kept within the following limits				As per EN50121-3-1, limits are variable between 150 kHz to 30 MHz and from 30 MHz to 1 GHz. Representation in tabular format may not be correct representation. Same is represented in figure 2 and figure 3.		
Field		Frequency, MHz	Radiated Field Limits at 10m(*)					
Magnetic Field		0.15	55					
(dB/μA/m)		30	5					
Electric Field		30	75					
dBm V/m		1000	50					
4	7.3.2	The Document does not mention the limiting values for “Requirement of Immunity for On Board Equipment”, although it details all Tests against relevant Standards. Please mention the boundary values in respect of the following parameters: (i) Conducted Emissions on (a) AC and DC Auxiliary supplies, (b) Battery Power Supply (ii) Total Harmonic Distortion (THD) on AC power supply outlet for public/staff use (THD< 8% at 50 Hz) (iii) Radiated Emission at 3 metres, applicable to all on-board systems, except for Traction Converters, Auxiliary Converters, which need to be tested individually but will also be tested at vehicle level with EN-50121-3. Please provide Quasi-Peak values at different			C	i) ii) iii) iv) v) vi) vii) viii) Already mentioned in section 7.3.1.1 Added in section 7.3.1.1 This is not required separately as per EN50121-3-2, 2016 version. This can be tested along with vehicle level radiated emission testing as per EN50121-3-1. Already mentioned in 7.3.2.1 Already mentioned in 7.3.2.3 Modified in section 7.3.2.2 Modified in section 7.3.2.4 Already mentioned in 7.3.2.5		

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BEML Submission Date: 03.07.2025

DB Review Date: 18.07.2025



BEML - High Speed Rail

SN.	Section Ref No.	DB E&C Comments	Review Status	BEML/Medha/EC-E Response	Sections Modified
		frequencies. (iv) Immunity to fast transient bursts on: - Battery operated reference Ports - Auxiliary AC power output ports, rated 400V rms - Signal & Communication ports - Process measurement and control ports (v) Immunity to conducted disturbances induced by EM Fields on - Battery operated reference Ports - Auxiliary AC power output ports, rated 400V rms - Signal & Communication ports - Process measurement and control ports (vi) Immunity to Surges on - Battery operated reference Ports - Auxiliary AC power output ports, rated 400V rms (vii) Immunity to Radio Frequency EM Field (viii) Immunity to Electrostatic Discharges (only for equipment accessible to passenger and operating staff, but not required for equipment accessible to maintenance staff).			

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BEML - High Speed Rail

SN.	Section Ref No.	DB E&C Comments	Review Status	BEML/Medha/EC-E Response	Sections Modified
5	Para 9 Page48/61	The relevant para distinguishes the cabling circuits only into three broad categories in accordance with EN 50121-1,2,3. However, based on experience with varieties of rolling stocks and the nature of modern equipment; we suggest further sub classifications as follows (<i>circuits are indicative and suggestive. Please write correct names in the Submittal</i>): Class A: Power Circuits (HV, MV and LV) A1: AC 25 kV power supply A2: DC Link (1500 V-2500 V) power supply A3: Cables between Traction Transformer (TFP) Secondary to next Equipment A4: Harmonic Filter on TFP Secondary Winding A5: DC Bus 2F Filter A6: Auxiliary Converter Smoothing Circuit A7: Traction Motor Cables A8: Auxiliary Network “non-sinus” output	C	Categorisation is done based on segregating the cables to avoid any conducted and radiated induction in one type of cables from other type of cables. In category all cables are high voltage cable having switching or at multiple of 50 Hz. Also, induction from one cable to other cable does affect the functionality in any way. Similarly, classification is done for class B and C. Also, EN50343 can be referred for such classification.	

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	DB Review Date: 18.07.2025



BEML - High Speed Rail

SN.	Section Ref No.	DB E&C Comments	Review Status	BEML/Medha/EC-E Response	Sections Modified
		A9: Auxiliary Network “sinus” output Class B: Battery Circuits and assimilated circuits B1: Battery Charger, Battery power supply of electronic units, Battery referenced ON/OFF), Management signals (management for relays, contactors, electro-valves, pressure switches, thermal switches etc.) B2: Class B assimilated circuits (e.g. Fire Detection, DC/DC Converter output for lighting/windscreen etc) Class C: Signal & Communication, Process Measurement and Management Circuits: C1: Management Circuits (e.g: Power Converter gate signals) C2: Sensors Circuits, 4-20 mA Circuits C3: Analog Audio and Video Circuits C4: Track/Train Communication Circuits C5: Low Level Sensors The Cables/Circuits of each sub-category may be bunched together separating these from other cables of same Category. The laying of Cables of each sub category may be bunched in a separate metal (earthed) conduit, or			

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BEML - High Speed Rail

SN.	Section Ref No.	DB E&C Comments	Review Status	BEML/Medha/EC-E Response	Sections Modified
		otherwise, as per the requirement.			
6		The Earthing Concept is only outlined and not elaborated in line with B28 Train concepts. A detailed study on potential rise at different parts of the Train and the mitigation of the potential rise thereof needs to be elaborated. The Earthing Concept must include “worst case scenarios” under Surge and Lightning of the System.	B	Refer Earthing Plan document (CD:3931 ,CD/FPPIC/TD/404) As power connection is directly done at ERCU in place carbody, there is no potential rise in carbody due to any short-circuit. Additionally for any functional earth even if earthing happens, current passed through car body is very less i.e., of the order of mA as there is no direct path for earth return. So, there is no potential rise in carbody.	
7		Suggestion for Adoption: Traction Return Current must be connected to Carbody first, before the Cable going to the Axles.		We do not agree to connect power return to carbody as it will high current through car body which may lead to lot of issue such as potential difference between different point of car body. Corrosion in bearing.	
8		A separate Document containing Dynamic EMI/EMC Test Protocol may be submitted for all EMI/EMC Tests. This may be a part of EMI/EMC Management Plan.		Noted, will be provided as part of vehicle test protocol document.	

Note:

1. The acceptance of these documents by DB E&C shall not be deemed as validation of your submission and nor does it infer their fitness for the purpose. DB E&C does not accept any liability for the submission.
2. Any changes to the documents should be undertaken in accordance with your organization’s approved change control procedures. Such variations must be formally recorded, and evidence should accompany any resubmission.
3. Without relieving the originating organization of their contractual responsibilities, the comments are as follows: -
 - a. Overall Category-D rejected, and a Category-C Returned for Corrections requires the whole document(s) to be revised and resubmitted to address the comments prior to any rework a way forward shall be agreed between supplier and the DB E&C representative.
 - b. Overall Category-A Notice of No Objection with amendments requires the appropriate responses with additional information to be submitted to address the comments.

DOCUMENT REVIEW SHEET	
Document No: FPIIC/TD/232	BEML Submission Date: 03.07.2025
	DB Review Date: 18.07.2025



BEML - High Speed Rail

SN.	Section Ref No.	DB E&C Comments	Review Status	BEML/Medha/EC-E Response	Sections Modified
c. Comments type-B, C and D requires a written response.					
4. Whenever any change occurs that invalidates the information contained in the previously submitted and reviewed document, within 14 days of the occurrence of such change; and when requested by the Client's Representative from time to time					
5. Review Comment Sheet is part of the Drawing/Document and shall be kept in the last pages of drawing/Document.					
Reviewer's Name:			Date:	18.07.2025	
Lead Reviewer's Name:			Date:	18.07.2025	
Approver's Name			Date:		
Document Review status terminology: C					
A: Notice of No Objection		B: Notice of No Objection with Comments	C. Returned for Corrections	D: Rejected	

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Document No: FPIIC/TD/232	BEML Submission Date: 03.07.2025
	DB Review Date: 18.07.2025