9. APTA PR-E-S-010-98
Standard for the Development of an Electromagnetic Compatibility Plan

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Abstract: This standard defines the requirements for an Electromagnetic Compatibility (EMC) Program for all rail equipment and track sided equipment delivered to the railroad to achieve safe operations. This Standard includes a requirement for an Electromagnetic Compatibility Control Plan (EMCCP), defines the classes of Electromagnetic Interference and Hazards, defines the minimum requirements of an Electromagnetic Compatibility Test Plan, Electromagnetic Compatibility Test Procedure and an Electromagnetic Compatibility Test Report.

Key Words: electromagnetic compatibility, electromagnetic interference, EMI

Introduction

(This introduction is not part of APTA SS-E-001-98, Standard for the Development of an Electromagnetic Compatibility Plan)

This introduction provides some background on the rationale used to develop this standard. This information is meant to aid in the understanding, usage and applicability of this standard.

Each railroad has over the years developed equipment, systems and environments that present unique susceptibility levels to energy from electromagnetic radiation and energy from conduction on power lines. Each railroad has developed their own emission and susceptibility levels to meet their unique environments. A minimum set of levels could be set but no one set of levels can fully assure safe operation on all properties at all times. Therefore, this standard does not attempt to set those levels, but rather it sets a uniform method of developing an Electromagnetic Compatibility Control Program and uniform testing to assure verifiable compliance with the levels set by each railroad.

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Standard for the Development of an Electromagnetic Compatibility Plan

1. Overview

1.1 Scope

This standard defines the requirements for an Electromagnetic Compatibility (EMC) Program for all rail equipment and track sided equipment delivered to railroads to achieve safe operations. This standard includes a requirement for an Electromagnetic Compatibility Control Plan (EMCCP), defines the classes of Electromagnetic Interference and Hazards, defines the minimum requirements of an Electromagnetic Compatibility Test Plan, Electromagnetic Compatibility Test Procedure and an Electromagnetic Compatibility Test Report. Outlines and minimum contents of these documents are included in sections 6 through 9 as indented italicized headers. This standard also contains the pertinent test level parameters that shall be specified for testing for levels of Electromagnetic Interference and Hazards and government documents containing acceptable test procedures.

The passenger rail industry phased this standard into practice over the six-month period from July 1 to December 31, 1999. The standard took effect January 1, 2000.

1.2 Purpose

The purpose of this document is to establish the minimum requirements for an EMC Program which is designed to prevent Electromagnetic Interference (EMI) in rail equipment and trackside equipment and to ensure that any newly acquired rail equipment will operate satisfactorily without EMI problems.

This document does not identify test requirements or procedures, instead it outlines a process to identify system requirements; produce a system that meets these requirements; and finally, verify that the requirements have been met. The key to this entire process is teamwork and communications. Each railroad has the ultimate responsibility for assuring electrical non-interference for the unique circumstances associated with their operations.

This process defines a team effort between the railroad and all members of the planning, development, manufacturing, operating and maintenance teams. As the responsible entity for the entire rail system, the railroad heads the team and owns all documents. A railroad may create this plan or have a vendor or contractor generate this plan. While it is the railroad’s responsibility to ensure the team is aware of all system requirements, it is every member’s responsibility to identify and bring to the attention of the entire team any system requirements that have not been identified. Communications and teamwork are the only way to ensure an EMC System.

Since communication is the key to success, this document describes key information that shall be presented to the team and agreed upon. This information may be described as documents, but does not necessarily refer to formal printed or electronic submittals - this is determined by the railroad and can require as much or as little formal documentation as desired. Successful EMC systems can be developed with limited formal documentation as long as communications and information transfer among the team is maintained.

2. References

EN 55011 1991 Radio Frequency Interference Suppression for Electrical Equipment and Systems

IEC-1000-4-2 1995 Electromagnetic Compatibility, Part 4 Testing and Measuring Techniques, Section 2 Electrostatic Discharge Immunity Test

IEC-1000-4-3 1995 and Amendment 1998-1: Electromagnetic Compatibility, Part 4 Testing and Measuring Techniques, Section 3 Radiated Radio Frequency Electromagnetic Field Immunity Test

IEC-1000-4-4 1995 Electromagnetic Compatibility, Part 4 Testing and Measuring Techniques, Section 4 Immunity to Electrical Fast Transient Burst

IEC-1000-4-5 1995 Electromagnetic Compatibility, Part 4 Testing and Measuring Techniques, Section 5 Surge Immunity Test

MIL-STD-462D Department of Defense Test Method Standard for Measurement of Electromagnetic Interference Characteristics

UMTA-MA-06-0153-85-8 1987 Inductive Interference in Rapid Transit Signaling Systems, Volume II: Suggested Test Procedures

UMTA-MA-06-0153-85-11 1987 Radiated Interference in Rapid Transit Signaling Systems, Volume II: Suggested Test Procedures

UMTA-MA-06-153-87-2 1987 Conducted Interference in Rapid Transit Signaling Systems, Volume II: Suggested Test Procedure

3. Definitions abbreviations and acronyms

3.1 Definitions

For the purpose of this recommended practice, the following definitions apply.

3.1.1 commercial equipment: Any equipment available on the general market not constructed specifically for the railroad. This includes medical devices such as pacemakers.

3.1.2 electromagnetic compatibility: The property of a system to operate as designed without degradation of operation and without causing degradation of operation of other equipment.

3.1.3 electrostatic discharge: The rapid transfer of electric charge (spark) between two bodies of different electrostatic potential (voltage) in proximity (air discharge) or in direct contact.

3.1.4 failure modes and effects criticality analysis: An analytical technique which uses the cause and severity of potential failure modes of a system to determine design requirements.

3.1.5 low voltage power supply: A stand alone device that creates isolated and regulated DC voltages for other electronic components and devices using the system DC battery for input. Common voltages are 5, 15, 19 and 24 volts.

3.2 Acronyms

AC	Alternating Current
CE	Conducted Emissions (See section 4.4)
CFE	Customer Furnished Equipment (See section 3.2)
CS	Conducted Susceptibility (See section 4.3)
EFT	Extremely Fast Transients
EMC	Electromagnetic Compatibility
EMCCP	Electromagnetic Compatibility Control Plan
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge (See section 3.2 and 4.7)
FCC	Federal Communications Commission
FMECA	Failure Modes and Effects Criticality Analysis (See section 3.2)
IE	Induced Emissions (See section 4.6)
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IS	Induced Susceptibility (See section 4.5)
LVPS	Low Voltage Power Supply (See section 3.2)
RE	Radiated Emissions (See section 4.2)
RF	Radio Frequencies
RS	Radiated Susceptibility (See section 4.1)
UUT	Unit Under Test

4. Classes of interference and hazards

Below are seven classes of interference and hazards that can impact the operation of rail equipment and trackside equipment that all Electromagnetic Control Programs must consider. A device can be a source of interference and/or susceptible to interference from the three different coupling modes, radiated, conducted, and induced, yielding six classes. A device that is a source of one coupling mode may be susceptible to another coupling mode, so all devices must be screened for all six classes. No Electromagnetic Control Program would be complete without considering the seventh class, Susceptibility to Electrostatic Discharge.

4.1 Susceptibility to radiated emissions (RS)

The equipment can be affected by radiated emissions from such sources as radios, transmitters (government, commercial and private) and other equipment in the vehicle and along the wayside.

4.2 Source of radiated emissions (RE)

The equipment can be the source of radiated emissions that can interfere with radios and other equipment in the vehicle and right of way equipment.

4.3 Susceptibility to conducted emissions (CS)

The equipment can be affected by conducted emissions through the power and signal wiring connected to the equipment from such sources as alarm bells, contactors, inverters, and other equipment in the vehicle.

4.4 Source of conducted emissions (CE)

The equipment can be the source of conducted emissions that can interfere with radios and other equipment in the vehicle or trackside enclosure through the third rail, running rail, power cabling or signal wiring.

4.5 Susceptibility to induced emissions (IS)

The equipment can be affected by the magnetic coupling of AC signals from one conductor to another or by emissions induced by the motion of one device with respect to another. The latter can occur from passing trackside equipment that has a normally acceptable field around it, but the motion of the rail equipment past the trackside equipment causes a current to be induced into the rail equipment through the track, by proximity to the trackside equipment or by other equipment on board with parallel conductor runs.

4.6 Source of induced emissions (IE)

The equipment can affect trackside equipment by generated AC fields or by the motion of the rail equipment past the trackside equipment. This causes a current to be induced into the trackside equipment through the track, by proximity to the trackside equipment, or to other equipment on board with parallel conductor runs.

4.7 Susceptibility to electrostatic discharge (ESD)

The equipment can be affected by electrostatic discharge from static buildup on a body discharged through contact with electrical devices such as a person touching a switch, through operation, maintenance or repair.

5. Electromagnetic compatibility control plan (EMCCP)

All rail equipment and trackside equipment shall be electromagnetically compatible within themselves, with all other rail vehicles and trains in operation on the property, with the property’s power system, with the property’s signal system, with the property’s communication system, with other electronic equipment on the property and with other electronic equipment along the right of way. To achieve this, an EMCCP shall be defined by the Rail Authority and all suppliers of electrical and electronic equipment to that railroad shall submit evidence of compliance to that control plan.

The EMCCP shall identify the entity that is responsible for achieving and documenting the Electromagnetic Compatibility, the EMI specifications being imposed on the equipment, and the conditions for final acceptability/ownership.

The EMCCP shall address all requirements set forth in the railroad's specification, including scope, purpose and requirements; project organization, schedule and deliverables; EMC design report; EMC safety analysis; emission limits; test plans; and testing. Any EMC procedures and testing that will be carried out on a routine basis on all production equipment after qualification testing is achieved shall also be listed. The EMCCP shall address all relevant government rules, regulations, laws, or certifications that may be required.

To start the communications, the EMCCP shall identify all team members. Even at the planning stage the team shall include manufacturing, operating, and maintenance members. All members shall work together to identify and document all system requirements and agree upon the validation process for each requirement. This is an ongoing process that will grow during the life of the system. As new parts are added to the system, new team members will come and go but the core and control of the team shall remain with the railroad.

6. Minimum requirements of an EMCCP

The EMCCP shall specify the objectives, scope, EMC program activities and schedule, EMC program deliverables and reporting, identity of the EMC organization and key participants, and methods and techniques by which the EMC program objectives will be met. The EMCCP shall contain at least the items in the outline below. Each railroad shall have the authority to add to or expand the items to meet their individual needs.

1. OVERVIEW

1.1 Scope:

Include a brief discussion covering the scope of the EMC program with respect to contractual EMC requirements.

1.2 Purpose:

State the objectives of the EMC program. Identify the originator of the plan and the organization to whom the plan is to be submitted.

2. APPLICABLE DOCUMENTS

List all EMC specifications applicable to the program. Include government and industry specifications, company documents, special requirements, any letters or other documents that may modify the basic specification guidelines, and source for special documents.

3. DESCRIPTION OF EQUIPMENT OR SYSTEM

Give a brief description including a block diagram of the equipment or subsystem. Discuss the intended function, physical size, operational environment, and specific operating characteristics such as frequency, power, and sensitivity.

4. PROGRAM RESPONSIBILITIES

At the minimum, the plan shall have a responsible engineer as a focal point. More complex projects may have the following sections as may be required by the system contract.

4.1 Management

Discuss the management support required for the effective implementation of the EMC program. Responsible management and project personnel shall be identified. An organizational chart can be included that illustrates lines of responsibility for EMC. Discuss the management controls, techniques and EMC objectives to be achieved. Define the EMC responsibility of all subcontractors. If the EMC engineering is to be subcontracted to a consulting firm, identify the firm and the individual who will be the EMC engineering contact or consultant.

4.2 Engineering

EMC engineering personnel assigned to the program shall be identified and specific responsibilities described, which can include a brief summary of experience as it pertains to EMC. A discussion of engineering objectives to be achieved shall be included.

4.3 Milestones

Identify the EMC program schedule milestones. Pertinent events may be used as milestones.

4.4 Supplier Coordination

Discuss plans for defining responsibilities and coordinating the EMC program with all suppliers. Note the degree of responsibility for subsystem interfaces and EMC characteristics where customer furnished equipment and other existing equipment are concerned.

5.TECHNICAL PROGRAM

5.1 EMC Requirements

All EMC requirements shall be identified.

5.2 Exceptions to EMC Requirements

Identify and state reasons for any exceptions to the EMC requirements that are applicable to the program. EMI Test Reports of any Customer Furnished Equipment (CFE) or Commercial Equipment (including medical devices such as pacemakers) that interfaces with other equipment or within the system shall be requested for analysis to determine if additional suppression is required.

5.3 EMC Concepts

Discuss the EMC concepts to be used to attain electromagnetic compatibility. For systems, this discussion shall include allocation of the requirements and the EMC program to equipment suppliers, design reviews including resolution of problems, and verification of the plan. For specific equipment, this discussion shall include methods of grounding, bonding, shielding, filtering, lead routing, ground return criteria, packaging, component selection, finishes, connectors and other pertinent factors. EMI control concepts described shall be compatible with the equipment or system operational environment such as trackside equipment, radios, emergency systems, etc.

5.4 Specific Design Considerations

Identify and characterize interference sources and discuss EMI reduction techniques and susceptibility control procedures. All EMI sources and receivers shall be considered and evaluated to determine those which pose a potential hazard to any on-board or wayside equipment. Sources and receivers include, but are not limited to: transformers, large inductors, rectifiers, braking choppers, traction inverters, traction motors, auxiliary transformer, auxiliary inverter, LVPS, battery charger, gate drive power supplies, microprocessor boards, all interconnecting wire and cable, cab signals, radios, on-board control systems, passenger information systems, wayside signals and transponders.

All EMI coupling modes shall be considered between each source and receiver. This includes conducted, induced and radiated EMI. One or more modes may be significant for each source or receiver. For example, any under-car-mounted component, such as large inductors, shall be examined for inductive coupling into the running rails. Any leakage flux emanating from the inductor and its cables is in a position to couple to the rails. Another example is a microprocessor board, which operates and can radiate at radio frequencies and might interfere with the cab voice radio.

5.5 Reviews

Discuss areas to be covered at EMC design reviews and proposed scheduling. There shall be a minimum of three reviews: a Concept Review, a Design Review, and a Verification Review (these terms may be different from railroad to railroad).

The Concept Review is held to demonstrate that all parties understand and acknowledge the requirements of the EMCCP.

The Design Review is held to demonstrate the equipment designs meet the requirements of the EMCCP.

The Verification Review is held at the culmination of the process to confirm that the equipment does meet the requirements of the EMCCP.

It is recommended that for complex systems, an EMC Oversight Committee be established including equipment vendors as members, to mitigate any issues that may arise. This allows issues to be brought forward and a resolution agreed upon prior to the reviews. In many cases, EMI problems result at the interfaces between one system and another, and often cross the lines between electrical, mechanical structure, materials and location layout disciplines. This focal point shall force consideration of the total design from an EMC view. For example, the location of the cab signal receiver coils may have to be changed as a result of evaluation of the EMI flux from the traction motor or its cables, or the routing or grouping of the traction motor cables might have to be changed.

5.6 EMI Safety Analysis

The EMI Safety Analysis shall address the provisions for adequate detection and annunciation response to failures that could cause EMI to increase above acceptable levels and shall include the following:

FMECA - A Failure Modes and Effects Criticality Analysis (FMECA) shall be performed to identify all potential EMI hazards to safety critical systems and mitigation methods. All normal operating modes of the train, and specified degraded performance modes with faults present, shall be included. The FMECA results are then used to determine what needs to be considered in the EMCCP.

Radiation Hazards - Discuss any precautions to be taken during the program in regard to equipment or system operation, RF power levels and possible radiation hazards.

Grounding and Shorting Hazards - Discuss any precautions to be taken during the program in regard to hazards that result from grounding faults or shorts.

5.7 Verification

The verification process shall be discussed. Verification of the EMCCP includes observation, demonstration, analysis and testing. Individual equipment may be verified using any of the four or a combination of the four as a valid verification method while the system may be verified only by testing. The equipment level verification is followed by laboratory testing at the system level and finally vehicle track testing.

<u>Inspection</u> is a qualification process of examining a piece of equipment for compliance by use of a checklist. More than one requirement may be listed on the checklist. A possible example of this would be a requirement to verify that a MOV is installed across a coil or that the ground terminal of a device is connected to the correct ground point.

<u>Demonstration</u> is a qualification process of operating similar equipment meeting a functional requirement in a similar environment. An example

would be demonstrating that a protection device functions at the right level.

Analysis is a qualification process requiring a report with attached copies of supporting computations. Analysis could be done with modeling and simulation using approved techniques.

Testing is a qualification process requiring a test plan, a test procedure, a test report and a resolution report where non-compliance is reported.

5.8 Vendor EMC Program

Stipulate that Vendors shall meet the specification requirements of the procurement EMC Specifications. The vendors shall follow the same guidelines for the System EMCCP including identifying engineers responsible for the Vendor EMC Program, establish requirements, including dates, for reviewing the EMC Program, reviews, test witnessing, and approval requirements for documents such as Control Plans, Test Procedure and Test Reports.

6. CONTROL PLAN REVISIONS

Include a statement concerning criteria for revising the EMCCP.

7. Test plan requirements

When formal verification of a component, sub-system, or system by test is required, a test plan, a test procedure, and a test report for the verification is required. The minimum requirements and contents of a test plan are outlined in this section. Each railroad may establish their own report formats, recording and documentation procedures to expand the plan.

1. INTRODUCTION

Include a brief description of the component, sub-system, or system the EMC Test Plan is for, and what contractual EMC requirements are to be verified under this Plan.

2. APPLICABLE DOCUMENTS

As a minimum, list the EMC plan and any document containing EMC pass/fail requirements for the unit under test (UUT) and any document containing required test procedures. Especially include any company documents, special requirements, letters or other documents that may modify the basic specifications. The source for all listed documents shall be included. An expanded version may list all EMC documents for the contract.

3. DESCRIPTION OF EQUIPMENT OR SYSTEM

Give a more detailed description of the UUT, including a block diagram showing the location of the UUT in the system and the decomposition of the UUT into individual components if applicable. Discuss the intended function, physical size, and specific operating characteristics such as frequency, power, and sensitivity of the UUT and UUT's operational environment.

4. PROGRAM RESPONSIBILITIES

4.1 Management

As a minimum, identify the person or organization responsible for the UUT, the person or organization responsible for the verification test, and the person or organization responsible for acceptance of the test. An expanded version may include a brief summary of credentials for key or every identified individual.

4.2 Milestones

Identify how the test program fits in the overall schedule. Pertinent events may be used as milestones. The plan shall consider early testing on similar units. (An early series of tests could be very valuable as an early indicator of potential problems.) Any preliminary testing shall be indicated. Preliminary testing does not require an approved test procedure or production of a test report; plans and results can be presented at standard scheduled reviews.

5. PLANNED TESTS

A brief description of each formal test scheduled, the requirement the test will verify, and a preliminary schedule, is required. The schedule shall include sufficient time to prepare, review, and approve the test procedures prior to testing. The description shall include the state of the UUT and any support equipment necessary, i.e. prototype, pre-production, or first article. Breadboard equipment shall not be used for formal verification and shall not be used for support equipment. Any special test equipment or facilities shall be identified.

8. Test procedure requirements

When formal verification of a component, sub-system, or system by test is required, a test plan, a test procedure, and a test report for the verification is required. The minimum requirements and contents of a test procedure are outlined in this section. Each railroad may establish their own report formats, recording and documentation procedures to expand the document, but it is recommended to keep the test procedure documents as simple as possible. As an example, multiple related tests can be included in one test procedure, such as different frequency band and power level in a radiated emission test. But separate test procedures are required for radiated and conducted susceptibility tests as they are dissimilar tests.

1. INTRODUCTION

Include a brief description of the component, sub-system, or system the EMC test procedure is for, and what contractual EMC requirements are to be verified by this test.

2. APPLICABLE DOCUMENTS

List, as a minimum, the EMC plan, the EMC test plan calling out this test, any document containing EMC pass/fail requirements for this test, and any document containing required test procedures. Especially include any company documents, special requirements, letters or other documents that may modify the basic specifications. The source for all listed documents shall be included. No documents superfluous to this test shall be included.

3. DESCRIPTION OF UNIT UNDER TEST (UUT)

Give a detailed description of the UUT, including a full wiring diagram showing all UUT connections to the system and if the UUT is composed of more than one component, all inter-connections. Input and output voltages and signal characteristics shall be included. If special length cables are required for the system it shall be noted.

4. UUT CHECKOUT PROCEDURES

Include or reference, detailed or step by step, procedures to verify the functionality of the UUT. These include hook up, initialization, and operation of the UUT and support equipment. Procedures and operational pass/fail criteria shall be listed for each mode of operation for the UUT.

5. TEST DESCRIPTION

For each mode of operation of the UUT run through the steps below:

1. Specify mode of operation of UUT and support equipment.
2. Specify Test Pass/Fail criteria.
3. Set up as needed.
4. Verify UUT meets all operational criteria.
5. Perform specified detailed test procedure.
6. Determine if test Passed or Failed.

6. DETAILED TEST PROCEDURE (optional if standard test)

The Detailed Test Procedures shall contain the following:

1. Block diagrams of the test equipment set up procedure.
2. Criteria for acceptable test equipment.
3. Steps to operate the test equipment.
4. List of any special environmental requirements.

9. Test report requirements

When formal verification of a component, sub-system, or system by test is required, a test plan, a test procedure, and a test report for the verification is required. The minimum requirements and contents of a test report are outlined in this section. Each railroad may establish their own report formats, recording and documentation procedures to expand the document, but it is recommended to keep the test report documents as simple as possible and directly linked to the formal test procedure documents.

1. INTRODUCTION

Identify the unit under test (UUT) and the test performed. State if the test passed or failed.

2. APPLICABLE DOCUMENTS

List the EMC plan, the EMC test plan, and the test procedure this report documents.

3. DESCRIPTION OF TEST FAILURE

Give a detailed description of the portion of the test that failed. Include results from any investigative measurements, including changes in the UUT, test equipment, or equipment settings. ONLY DECLARE A TEST FAILURE IF THE UUT FAILS TO MEET THE PASS/FAIL CRITERIA INCLUDED IN THE TEST PROCEDURE. If a piece of support equipment fails, do not count the failure against the UUT if the UUT passes all requirements. If the test cannot continue without the support equipment, declare the test incomplete.

4. TEST MEASUREMENT APPARATUS

List each piece of test equipment used by name and serial number. Calibration due date shall also be included.

5. TABULATION OF RESULTS

Include copies of all data acquired during the test, including any special settings on test equipment to isolate fault conditions.

6. TEST NOTES

Include copies of all notes recorded during the test.

10. Acceptable test procedures and levels

This section describes the general requirements for each of the seven different EMC tests below. For each test, the railroad shall specify at least one test level with associated performance pass/fail criteria and an acceptable test procedure, such as a MIL-STD, IEC, UMTA, or site specific test. The necessary parameters to define a test level are specified. The following sections contain examples of accepted test procedures by various railroad and are included to be representative but not all inclusive of the available test procedures.

10.1 Susceptibility to radiated emissions

Radiated susceptibility tests expose the UUT to predefined minimum electric field levels over a defined frequency range. An example of a two level specification is: “No permanent degradation of performance when tested to IEC-1000-4-3 at Level 3, but interference is allowed during the test. No operational degradation when tested to Level 1.” This example specifies two levels with associated pass/fail criteria and the acceptable test procedure. Two levels are needed because two different pass/fail criteria exist.

Examples of acceptable test procedures are IEC-1000-4-3 or MIL-STD-462D.

The frequency range, the Field Strength, polarity, modulation content, and dwell time or sweep rate are required to define a test level specification.

10.2 Source of radiated emissions

Radiated emission tests measure the amount of electric and/or magnetic field emitted by the UUT at various frequencies, distances, and bandwidth. An example specification is: “All emissions shall be below FCC Part 15 Class A levels when tested according to MIL-STD-462D RE102 procedures.” This example is a single level test because only one pass/fail criteria exists, even though FCC Part 15 specifies different levels at different frequencies.

Examples of acceptable test procedures are UMTA-MA-06-0153-85-11, EN 55011 or MIL-STD-462D.

The frequency range, field strength, polarity, bandwidth, detection mode (peak, average, or quasi-peak), and distance from UUT are required to define a test level specification.

10.3 Susceptibility to conducted emissions

Conducted susceptibility tests expose the UUT to abnormal conditions on the power input and return and signal lines. Different test procedures and equipment are needed for each type of voltage spike, such as surge or extremely fast transient (EFT) tests. An example EFT specification is: “All components and devices shall operate without any failure or degradation in performance when tested according to IEC 1000-4-4 procedures at Level 1. All components and devices shall operate without permanent failure or permanent degradation in performance when tested according to IEC 1000-4-4 procedures at Level 3, but upset and automatic reset are allowed during test.” This is an example of a two level test because two pass/fail criteria exist.

Examples of acceptable procedures are *UMTA-MA-06-153-87-2, MIL-STD-462D, IEC 1000-4-4, and IEC 1000-4-5.*

The transient peak, polarity, rise-time, duration, repetition rate and either energy content or source impedance are required to define a test level specification. The coupling mode must also be specified, such as across the lines, differential mode, or from line to ground, common mode.

10.4 Source of conducted emissions

Conducted emission tests measure the voltage or current the UUT emits on the power input and return and signal lines. These emissions can be measured in the frequency and/or time domain. Time domain measurements are needed to detect maximum transient emissions that are specified by peak voltage, duration, and repetition rate. Frequency measurements are specified by maximum amplitude over a frequency range when measured into a defined impedance. An example time domain specification is: "No equipment shall produce ripple, spikes, sags, or transients greater than 5% of the input voltage on the power and power return lines."

Examples of acceptable procedures are *UMTA-MA-06-153-87-2, MIL-STD-462D, EN 55011*[1].

The allowed transient or steady state peak, polarity, rise-time, duration, repetition rate and either energy content are required to define a test level specification. The coupling mode must also be specified, such as across the lines, differential mode, or from line to ground, common mode.

10.5 Susceptibility to induced emissions

The induced tests are specific tests developed for the rail industry to duplicate conditions present in signaling and power systems. These tests shall specify both the source and receiver configurations.

UMTA-MA-06-0153-85-8 contains examples of acceptable procedures.

10.6 Source of induced emissions

The induced tests are specific tests developed for the rail industry to duplicate conditions present in signaling and power systems. These tests shall specify both the source and receiver configurations.

UMTA-MA-06-0153-85-8 contains examples of acceptable procedures.

10.7 Susceptibility to electrostatic discharge (ESD)

ESD tests expose the UUT to ultra fast, high voltage and current pulses. There are different models for the source of the pulse such as human body, furniture, or screw driver. Each model describes a different peak value of voltage and current with different rise time and duration. There are also different coupling modes, such as air discharge, contact discharge, near field radiated or conducted coupling. An example specification is: "All cards shall operate without failure or degradation in performance after exposing the unpowered card to 4 KV air discharges according to IEC 1000-4-2 or equivalent procedure. Any card unable to meet this requirement must be labeled static sensitive and obtain railroad approval for use."

For most devices the test and levels defined in *IEC 1000-4-2* are appropriate.

[1] For references in Italics, see Section 2.