# Electromagnetic Compatibility Specification For Electrical/Electronic Components and Subsystems

**Foreword**

This engineering specification addresses Electromagnetic Compatibility (EMC) requirements for electrical/electronic (E/E) components and subsystems for Ford Motor Company (FMC). This specification is the direct link from RQT-002700-000417 (Legacy Requirement ARL-09-0466). These requirements have been developed to assure compliance with present and anticipated regulations in addition to customer satisfaction regarding the EMC of vehicle E/E systems. This specification replaces EMC-CS-2009.1.

FMC1278 is applicable for all 12 and 24 volt DC E/E components/subsystems that are planned for use on 2020 Ford vehicle programs and beyond in addition to E/E component/subsystems whose commercial agreements are signed after July 1, 2015.

FMC1278 is available for download from the Ford Standards Management System (FSMS) in addition to www.fordemc.com Corrections and/or editorial updates to this specification will be made as required and without prior notification to the user. It is recommended that the user verify they have the latest version of the specification prior to application to their E/E component/subsystem. Differences between this specification and its prior release may be found in Annex I

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# 1.0 Scope

This engineering specification defines the Electromagnetic Compatibility (EMC) requirements, test methods and test procedures for electrical/electronic (E/E) components and subsystems used by Ford Motor Company (FMC) including associated vehicle brands.

## 1.1 Purpose of the Specification

The purpose of this engineering specification is to ensure vehicle Electromagnetic Compatibility. This specification presents EMC requirements and test methods that have been developed for design verification of E/E components and subsystems independent of the vehicle. Successful completion of this verification directly supports FMC's Production Product Acceptance Process (PPAP). Verification testing must be successfully completed before VP MRD. See FMC1279 for detailed requirements.

## 1.2 Vehicle Level Requirements

**In addition to meeting the requirements specified herein, E/E components and subsystems, when installed in the vehicle, shall also comply with all relevant vehicle level EMC requirements.**

The supplier may contact the FMC EMC department for details concerning these requirements *(these requirements are not publically available)*. Verification testing to these requirements is performed by FMC. Additional component, subsystem, and vehicle level EMC requirements may be imposed reflecting special conditions in their target markets. The component or subsystem supplier should verify that any additional requirements, or modifications to the requirements delineated herein shall be included in the supplier's statement of work and the component/subsystem's engineering specification.

## 1.3 Use of this Specification

The requirements and test methods in this engineering specification are based on international standards wherever possible. If international standards do not exist, military, and internal corporate standards are used. Under some circumstances, unique requirements and test methods are presented that experience has shown to better represent the vehicle electromagnetic environment. Refer to the definitions in Section 3.0 for clarification of terms. Should a conflict exist between this specification and any of the referenced documents, the requirements of this specification shall prevail. These requirements do not supersede any applicable regulatory requirements. Where such requirements exist, separate validation testing may be required.

This specification applies to all components and subsystems that reference EMC in their engineering specification. Components may be referred to in this specification as a component, device, module, motor, product or DUT (device under test). The following steps shall be taken by the FMC Design and Release (D&R) activity and their supplier for assuring EMC compliance of their component or subsystem:

1. Provide the supplemental information needed to classify the E/E component/subsystem functional importance classification(s) (refer to section 4).
2. Identify which tests are applicable (refer to section 7).
3. Identify operating modes and acceptance criteria specific to the component or subsystem.
4. Develop an EMC test plan per section 5.2 in FMC1279 (formally EMC-P-2009).
5. Perform testing at a FMC recognized test facility.
6. Submit the test results to the FMC EMC department. *See section 6.6 for reporting requirements.*
7. FMC reviews and assesses the test results and verify compliance.

It's important to emphasize that the FMC D&R activity and their supplier (not the FMC EMC department) are responsible for determining the operating modes and acceptance criteria for their component or subsystem (step 3). The FMC D&R activity is also responsible for verifying that the requirements delineated in this specification are met. The supplier is responsible for performing the verification testing in accordance with the requirements of this specification.

The FMC EMC department reserves the right to perform audit testing or witness supplier design verification testing on sample parts in order to verify compliance with this specification.

**Compliance to these EMC requirements shall be determined by the FMC after review of the test results generated by the test laboratory. The supplier may not self-certify compliance to these specifications.**

See section 6.6 for additional detail concerning this requirement.

### 1.3.1 Special Circumstances

The requirements specified herein apply to all E/E components and subsystems. However, under special circumstances (e.g. unique packaging environment), selected requirements may be revised or waived. These revisions or waivers are only permissible after a joint review and documented agreement between the FMC functional owner and the FMC EMC department. Those revisions/waivers must be also documented in the affected component or subsystem hardware specification prior to commencement of any sign-off related testing. Agreed to revisions or waivers do not relieve the component or subsystem from meeting the vehicle level requirements (see section 1.2).

## 1.4 Additional Information

E/E component or subsystem testing to the requirements of this specification represents an empirical risk analysis of component/subsystem performance versus derived approximations to known environmental threats and customer satisfaction requirements. The development of this specification is based on extensive experience in achieving correlation to expected vehicle performance with a high level of predictability. However, EMC testing, by its nature, is subject to similar variation as mechanical testing. Because of coupling variability and measurement uncertainty, correlation between component/subsystem level performance and final performance in the complete vehicle cannot be exact. In order to maintain a competitive and quality product, vehicle EMC testing will be performed to evaluate overall integrated system performance. However, vehicle level analysis and testing is not a substitute for component/subsystem conformance to this specification.

This specification does not include any information regarding component/subsystem design required to meet the requirements presented herein. Information on this subject may be found in ES-3U5T-1B257-AA "*EMC Design Guide for Printed Circuit Boards*", which is available for download from http://www.fordemc.com. Additional information may be found from a number of technical journals and textbooks.

Requirements contained herein that pertain to conducted emissions or immunity are limited to 12VDC and 24 VDC systems. Conducted requirements pertaining to higher voltage systems are not covered in this specification. However high voltage systems must comply with other EMC requirements (e.g. RF emissions/immunity, ESD requirements) as delineated herein. See Table 7-2 for specific applicability.

Although every attempt has been made to assure the information contained herein is accurate, editorial updates and/or technical clarifications to requirement/test methods are made when noted. This information may be found at http://www.fordemc.com. The user (i.e. suppliers, test laboratories) shall review this information prior to preparation of component EMC test plans and/or execution of testing.

# 2.0 References

## 2.1 International Documents

Only the latest approved standards are applicable unless otherwise specified.

**72/245/EEC. European Community, Electromagnetic Compatibility of Vehicle**

**CISPR 16-1-1**Specification for radio disturbance and immunity measuring apparatus and methods - Part 1: Radio disturbance and immunity measuring apparatus.

**CISPR 25** Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on board vehicles.

**ECE Regulation 10.05 Uniform provisions concerning the approval of vehicles with regard to electromagnetic compatibility**

**IEC 61000-4-21** Electromagnetic Compatibility (EMC) - Part 4-21: Testing and measurement techniques - Reverberation chamber test methods

**ISO 10605** Road vehicles - Test methods for electrical disturbances from electrostatic discharge

**ISO 7637-1** Road vehicles, Electrical disturbance by conduction and coupling Part 1 – Definitions and general considerations.

**ISO 7637-2** Road vehicles, Electrical disturbance by conduction and coupling Part 2 - Vehicles with nominal 12 V or 24 V supply voltage - Electrical transient transmission by capacitive and inductive coupling via supply lines

**ISO 11452-1**Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 1: General and definitions

**ISO 11452-2-2004** Road vehicles, Electrical disturbances by narrowband radiated electromagnetic energy - Component test methods Part 2 - Absorber-lined shielded enclosure

**ISO 11452-4** Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 4: Bulk current injection (BCI)

**ISO 11452-8**Road vehicles -- Component test methods for electrical disturbances from narrowband radiated electromagnetic energy -- Part 8: Immunity to magnetic fields

**ISO 11452-9** Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 9: Portable transmitters

## 2.2 Other Documents

**ES3U5T-1B257-AA** EMC Design Guide for Printed Circuit Boards. Available at http://www.fordemc.com/

**FMC1279** EMC Processes

# 3.0 Abbreviations, Acronyms, Definitions, & Symbols

**Acceptance Criteria.** Defines the limits of variance in function performance of the device during exposure to an electromagnetic disturbance.

**Active Electronic Module.** Electronic modules that function via use of digital or analog circuitry including microprocessors, operational amplifiers, and memory devices.

**ALSE.** Absorber-lined shielded enclosure. Also used in this document together with ISO or SAE to designate the test itself with reference to the method described in ISO 11452-1 or SAE J1113-21.

**AM.** Amplitude Modulation

**Annex.** Supplementary material attached to the end of a specification, often used to supply additional information that may be normative or informative in nature.

**Artificial Network (AN).** A device used to present a known impedance to the powerline of the DUT.

**Average Detection (AVG).** A detection method that produces an output voltage of which is the average value of the envelope of an applied signal. The average value must be taken over a specified time interval.

**BCI.** Bulk Current Injection. Method for coupling common mode RF current into a harness

**Buffered Power.** A voltage supply typically at the same magnitude as the vehicle's battery voltage (e.g. 13.5 VDC). Buffered power is typically derived using passive devices within the module including resistors, capacitors and inductors. Buffered power supplies are typically used to provide power from one module to another (e.g. radio tuner provides buffered power to a remotely attached antenna pre-amplifier module)

**Carry Over.** References a production level component designed to a current or previous EMC specification

**CBCI.** Common Mode BCI.

**CE.** Conducted Emissions

**CI.** Conducted Immunity

**CISPR.** An acronyme for "Comité International Spécial des Perturbations Radioeléctriques" (Special International Committee on Radio Interference).

**CLD**. Centralized Load Dump

**Component.** Reference for active electronic modules, electric motors, passive and inductive devices

**Control Circuits.** I/O circuits that are connected to the vehicle battery via switches, relays or resistive/inductive loads, where that load is fed by a direct or switched battery connection.

**Component, subsystem Engineering Specification.** Engineering specification for the component or subsystem documenting all performance requirements (mechanical, thermal, EMC, etc)

**D&R.** Design and Release

**dBpT.** dB picotesla (160 dBpT = 1Gauss )

**Disturbance.** Any electrical transient or electromagnetic phenomenon that may affect the proper operation of an electrical or electronic device (see stimulus).

**DBCI.** Differential Mode Bulk Current Injection.

**DUT.** Device(s) Under Test. Any electrical or electronic component, module, motor, filter, etc being tested. A DUT could also be comprised of a group of modules that make up a subsystem.

**E/E.** Electrical and/or Electronic.

**EMC.** Electromagnetic Compatibility

**EMI.** Electromagnetic Interference

**Effect.** A detectable change in DUT performance due to an applied stimulus.

**EM.** Electronically Controlled Motor.

**ESA.** "Electrical/electronic sub-assembly" as defined in section 2.8 of ECE Regulation 10.05

**ESD.** Electrostatic discharge.

**ESD - Air Discharge.** Test method whereby the electrode of the test generator is brought near the DUT and discharge is accomplished through an arc to the DUT.

**ESD - Contact Discharge.** Test method whereby the electrode of the test generator is brought into contact with the DUT and the discharge is triggered by the discharge switch located on the generator.

**Fail-Safe Recovery Strategy.** A predictable strategy for recovery of a function to normal operation (Status I) following removal of a significant stimulus that cause degradation to the function.. Functional recovery shall occur without permanent loss of function or corruption of stored data or diagnostic information. The recovery strategy cannot affect Immunity Related Functions (IRF).

**FMC.** Ford Motor Company including all affiliate brands

**FMC D&R activity.** The FMC engineering activity responsible for design or the component or subsystem

**FMC EMC Department**. The Ford Motor Company EMC department associated with a specific brand.

**FPDS.** Ford Product Development System

**Function.** The intended operation of an electrical or electronic module for a specific purpose. The module can provide many different functions, which are, defined (functional group and acceptable performance) by the module specification.

**Functional Performance Class**: Defines the importance of E/E component/subsystem functions with respect to overall operation of the vehicle. Class definitions are also based on the Immunity Related Functions as defined in ECE Regulation 10.5.

**Function Performance Status.** Defines the performance of DUT functions, when subjected to a disturbance,

**Inductive Device.** An electromechanical device that stores energy in a magnetic field. Examples include, but not limited to solenoids, relays, buzzers, and electromechanical horns.

**Informative.** Additional (not normative) information intended to assist the understanding or use of the specification.

**I/O.** Input and output. Also used in this document to designate the transient pulse testing on I/O-lines.

**MBW**. Measurement System Bandwidth

**Memory (temporary or permanent).** Computer memory used for, but not limited to storage of software code, engine calibration data, drive personalization, radio presets. Hardware for this includes ROM, RAM and FLASH memory devices.

**N/A**. Not Applicable

**Normal Operation:** In the context of functional performance status) A predictable and safe operating mode where the operator has full control.

**Normative**. Provisions that are necessary (not informative) to meet requirements.

**OBDII**. On-Board Diagnostics II

**PCB.** Printed Circuit Board.

**PD. Pulse Duration**

**Peak Detection (PK).** A detection method that produces an output voltage of which is the peak value of an applied signal.

**PM.** Pulse Modulation

**PRR.** Pulse Repetition Rate

**PPAP.** Production Part Approval Process.

**Production Representative.** Components being tested are built using production representative hardware and software constructed using production representative processes

**PWM.** Pulse Width Modulated or Modulation.

**Quasi-Peak Detection (QP).** A detection method having specified electrical time constants which, when regularly repeated identical pulses are applied, produces an output voltage which is a fraction of the peak value of the pulses, the fraction increasing towards unity as the pulse repetition rate is increased.

**RE.** Radiated Emission

**RESS**. rechargeable energy storage system that provides electric energy for electric propulsion of the vehicle.

**RI.** Radiated Immunity

**Recognized Laboratory.** An EMC laboratory that meets the requirements for acceptance by Ford Motor Company Refer to http://www.fordemc.com for more details on this program.

**Regulated Power Supply.** A voltage regulated supply typically lower in magnitude than the vehicle's battery voltage (e.g.,. 5VDC, 3VDC). Regulated power is derived using active electronic devices including linear and switch-mode power supplies. Regulated power supplies are typically used to provide power to sensors.

**RF Boundary.** An element of an EMC test setup that determines what part of the harness and/or peripherals is included in the RF environment and what is excluded. It may consist of, for example, ANs, filter feed-through pins, fiber optics, RF absorber coated wire and/or RF shielding. The RF boundary directly affects the resonant characteristics of the DUT cable harness during radiated immunity and emissions testing.

**Shall.** Denotes a requirement.

**Single Shot.** Refers to the capture mode of a digitizing oscilloscope. A single shot represents a single capture of the voltage or current waveform over a defined sweep time setting.

**Should.** Denotes a recommendation.

**Substitution Method.** The substitution method is a technique for mapping out the power required to produce a target RF field, magnetic field, or current in absence of the DUT at a designated reference position. When the test object is introduced into the test chamber, this previously determined reference power is then used to produce the exposure field.

**Switched Power Circuits.** Any circuit that is connected to the vehicle battery through a switch or relay.

## 4.0 Functional Classification and Functional Performance Status

All component and subsystem functions shall be classified per according to their criticality ("Functional Importance) in the overall operation of the vehicle. Functional Important Classifications are listed in Table 4-1. It is important to note that the definitions for Classes C and B are fully aligned with ECE Regulation 10.05 definition for "Immunity Related Functions".

If new functions are introduced, the FMC functional owner shall work with the FMC EMC department to develop and agree on the appropriate classification(s).

Once functional classifications are established, the associated performance requirements ("Functional Performance Status") are defined for each of the requirements herein. These generic performance requirements, listed in Table 4-2, serve as the basis for the component/subsystem acceptance criteria used during EMC testing. Component/subsystem specific performance requirements shall be established and documented in the EMC test plan per section 6.1. The FMC D&R activity and their supplier(s) shall be responsible for developing these performance requirements. Revisions to the generic functional status, as delineated in Table 4-2, requires review and written concurrence from the FMC EMC department. Those deviations must be also documented in the affected component or subsystem hardware specification prior to commencement of any sign-off related testing.

**Table 4-1: Functional Importance Classifications**

Class C:

a) Functions whose degradation may affect direct control of the vehicle:
   i. Degradation or change in: e.g., engine, gear, brake, suspension, steering, speed limitation devices.
   ii. Affects driver's position: e.g., seat or steering wheel positioning.
   iii. Affects driver's visibility: e.g., headlamp outage, dipped headlamp beam, windscreen wiper.

b) Functions whose degradation affects driver, passenger and other road user's protection (e.g., airbag and safety restraint systems).

c) Functions whose degradation can cause confusion to other road users:
   i. Optical disturbances: incorrect operation of: e.g., stop lamps, end outline marker lamps, rear position lamp, direction indicators, light bars for emergency system.
   ii. Acoustical disturbances: incorrect operation of (e.g. anti-theft alarm, horn).

d) Functions related to vehicle data bus functionality whose degradation can lead to blocking data transmission which is required for Class C functionality.

e) Functions whose degradation could cause unexpected vehicle motion while the vehicle is connected to an electric charging station.

Class B:

a) Functions that enhance, but are not essential to the direct control of the vehicle.

b) Functions whose degradation can cause confusion to the driver:
   i. Optical disturbances: incorrect operation of: e.g., direction indicators, wrong information from warning indicators, gauges, lamps or displays.
   ii. Acoustical disturbances: incorrect operation of (e.g. audible warnings, > 50% increase in volume from multimedia system).

c) Functions whose degradation affects statutory data (e.g. tachograph, odometer).

d) Functions related to vehicle data bus functionality whose degradation can lead to blocking data transmission which is required for Class B functionality.

Class A:

Functions used for convenience and/or are not covered by classes C or B

**Table 4-2: Functional Performance Status**

Status I:
- The function operates without deviation (within specified tolerances defined in EMC test plan) during and after exposure to the disturbance.

Status II [(1)]:
- The function deviates from normal design performance and is perceptible to the customer.
- The deviation does not impact safety or significantly impact customer satisfaction.
- After the disturbance is removed, recovery of normal function shall occur within a time equal or lower to that at startup (i.e. key-on). Alternatively, recovery shall be in line with a documented recovery strategy that does not require the driver to perform any actions that are considered unsafe while the car is in motion (e.g. IGN Key cycle)
- No effect on temporary or permanent type memory is allowed.
- The deviation in performance does not affect other related functions requiring Status I performance

Status III**:**
- The function deviates from normal design performance and is perceptible to the customer.
- The deviation does not impact safety or significantly impact customer satisfaction.
- After the disturbance is removed, recovery of normal function is not automatic and may require the driver to stop the vehicle to safely return the function to normal operation (e.g. IGN Key cycle)
- No effect on permanent type memory is allowed.
- The deviation in performance does not affect other related functions requiring Status I performance

Status IV:
- The device shall not sustain damage, changes in I/O parametric values (resistance, capacitance, leakage current etc.) or a permanent reduction in functionality.

(1) Under certain conditions, visual diagnostic indication (e.g. lamps, messages) may exhibit Class III performance, but requires review and acceptance by the FMC D&R activity. The associated base function must fully meet Status II performance.

# 5.0 Common Test Requirements

- Attention shall be directed to control of the RF boundary in both emission and immunity tests to reduce undesired interaction between the DUT, the Load Simulator and the electromagnetic environment.
- The test equipment, test setups and test procedures shall be documented as part of the test laboratory's procedures. FMC reserves the right to inspect the lab procedures.
- Although testing generally involves only one DUT, subsystem testing involving multiple DUTs (e.g. distributed audio components) is permissible.
- Production representative hardware and software shall be used for all verification testing unless approved by FMC EMC.
- All design verification testing requires an EMC test plan in accordance with the requirements of **FMC1279**. See section 6.1 for additional details.

## 5.1 Load Simulator

DUT operation shall be facilitated by use of a Load Simulator that is constructed to simulate the vehicle system. The Load Simulator, is a shielded enclosure that contains all external electrical interfaces (sensors, loads, etc.) normally seen by the DUT. The Load Simulator also serves as an RF boundary for the DUT cable harness in addition to serving as an interface to support and monitoring equipment required during testing. The Load Simulator shall be directly bonded to the ground plane except where noted in this specification. Detailed requirements for the Load Simulator are found in Annex F.

## 5.2 Artificial Networks

Several tests in this specification require the use of Artificial Networks. Unless otherwise stated in this specification, the use and connection of Artificial Networks shall be in accordance to the setup shown in Annex F. Artificial Network design and performance characteristics shall conform to the relevant CISPR and ISO standards (e.g. CISPR 25, ISO 11452-2, ISO 7637-2) where applicable.

Note: Use of Artificial Networks for most test methods in this specification deviate from CISPR/ISO specifications. See Annex F for additional detail.

## 5.3 Interconnections

The electrical interconnections between the DUT and Load Simulator shall be facilitated using a standard test harness. The length of this harness shall be 1700 mm +300/- 0 mm unless otherwise stated within this specification. The harness shall contain wiring types (e.g. twisted wire pairs) that are used in the actual vehicle installation. Selected tests (e.g. CE420) require shorter power/power return wiring between the DUT and measurement system. To avoid fabrication of multiple test harnesses, it is recommended that a single test harness be fabricated to facilitate removal of these selected circuits and to provide a method to reduce their physical length (e.g. in-line connector).

## 5.4 Bonding of DUT, Load Simulator and Artificial Network to Ground Plane

The Load Simulator and Artificial Networks shall be directly bonded to the ground plane used in the test setup. Bonding shall be facilitated via screws directly into the ground plane. The bond impedance shall be verified to be less than 2.5 mΩ. The same requirements apply to DUTs with metal cases that are to be directly bonded to the ground plane (specified in the EMC test plan). Use of conductive tapes for bonding is prohibited unless permitted by the FMC EMC department. *Approval requires specific process steps by laboratory to demonstrate bonding impedance remains stable over the duration of testing.*

## 5.5 Test Conditions

### 5.5.1 Dimensions

All dimensions in this document are in millimeters unless otherwise specified.

### 5.5.2 Tolerances

Unless indicated otherwise, the tolerances specified in Table 4.1 are permissible.

**Table 5-1: Permissible Tolerances**

| | |
|---|---|
| Time interval, length* | ± 10 % |
| Resistance, capacitance, inductance, impedance* | ± 10 % |
| Test parameters for RF Electrical or magnetic field strength, RF power, Injected RF current | -0 / +1 dB |

** Higher tolerance ratings shall be considered during the design phase of the component or subsystem*

Tolerances listed do not pertain to acceptance criteria for the DUT during testing.

### 5.5.3 Environmental Test Conditions

Unless indicated otherwise, the climatic test conditions are defined in Table 4-2.

**Table 5-2: Environmental Test Conditions**

| | |
|---|---|
| Temperature | 23 ± 5.0 degrees C |
| Humidity | 20 to 80% relative humidity (RH) |

### 5.5.4 Power Supply

The "Power Supply", used for energizing 12 and 24 VDC components and subsystems, shall meet the following requirements unless otherwise stated within this specification:

**Table 5-3: Environmental Test Conditions**

| System DC voltage | Power Supply Voltage Used for Testing |
|---|---|
| 12 | 13 (+ 0.5/-1.0) |
| 24 | 26 (+ 1/-2.0) |
| Other voltages (e.g. 3, 5 $V_{DC}$) | $V_{DC}$ (± 5 %) |

Unless otherwise stated for individual test methods, the "Power Supply" shall be a regulated DC supply in parallel with a battery. Inclusion of the battery is important when testing devices with high dynamic current demands (e.g. pulsed circuits). When performing testing per test methods RE 310, CE 420 and CE 421, the regulated DC supply should be a linear type to minimize test setup ambient noise. Alternatively, a switched mode supply may be used if it is located outside of the test chamber with adequate filtering at the test chamber interface connection. Regardless of the method used, the test setup ambient requirements must be met (See sections 8.3, 9.3, 10.3).

## 6.0 Additional Requirements

### 6.1 EMC Test Plans

An EMC test plan shall be prepared and submitted to the FMC EMC department at least 20 days prior to commencement of EMC testing. The purpose of this test plan is to develop and document well thought out procedures to verify that the component is robust to the anticipated electromagnetic environment that it must operate within. The EMC test plan also provides a mechanism for ongoing enhancements and improvement to the test setup, which better correlates with vehicle level testing.

The EMC test plan shall be prepared in accordance with the outline shown in FMC1279. FMC reserves the right to review and challenge specific detail of the EMC test plan including specific acceptance criteria for immunity testing. When the test plan is accepted by FMC, a unique test plan number will be assigned along with the EMC engineer sign-off. This test plan number will serve as reference for subsequent test results. **Failure to obtain this test plan number and EMC engineer sign-off prior to commencement of testing will invalidate the test results**. See FMC1279 for additional detail. Acceptance of the EMC test plan by FMC does not relinquish the supplier from responsibility if latter review shows deficiencies in the test setup and/or the acceptance criteria. The supplier shall work with the FMC EMC department to correct any deficiency and repeat testing if required by FMC.

### 6.2 Test Sample Selection

A minimum of two samples of identical design/function shall be tested. If there are multiple variants of the component (e.g. different PCBs, different PCB content), testing of these variants (2 samples each) will be required unless waiver is provided by the FMC EMC department. All applicable tests are performed on each of the samples unless approved by the FMC EMC department,

### 6.3 Sequence of Testing

ESD tests, both unpowered and powered (see Section 25) shall be performed prior to any other testing. It is recommended that RF Emissions (RE 310) and RF Immunity (RI 112/114/115) should be performed first following ESD testing. All remaining tests may be performed in any order. Extra test samples are recommended in the event of damage due to ESD. However, retesting will be required as the result of any corrective design actions required to mitigate any ESD issues found. In the event of damage to either test sample, testing shall be discontinued and the FMC EMC department contacted immediately for guidance. Failure to follow this process may result in non-acceptance of the test results.

### 6.4 Revalidation

To assure that EMC requirements are continually met, additional EMC testing may be required if there are any circuit or PCB design changes (e.g. die shrinks, new PCB layout) in addition to any software changes. The process presented in **FMC1279** shall be used to determine what additional testing will be required. The FMC EMC department and the FMC D&R activity shall be notified if any of the design changes outlined in **FMC1279** are planned.

### 6.5 Test Laboratory Requirements

All formal verification testing to support PPAP shall be performed in a recognized EMC test facility. A list of recognized test facilities may be found at http://www.fordemc.com. Laboratories seeking recognition by FMC shall do so via the process found at http://www.fordemc.com. Details on this program and steps for laboratory recognition may be found at http://www.fordemc.com.

FMC reserves the right to arrange for follow-up correlation tests and/or on site visits to evaluate the test methods presented herein. A laboratory which refuses such follow-up activities, or for which significant discrepancies are found is subject to having its recognition withdrawn. **FMC1279** provides additional details on EMC test facility requirements.

Developmental testing may be performed at any test facility, however those results will not be accepted for sign-off by FMC.

### 6.6 Data Reporting

Data reporting requirements, including processes for test report generation and submittal to the FMC EMC department are found in **FMC1279**.

- The test laboratory shall document all deviations from normal device functionality (i.e. Status I) during immunity testing. The lab shall not make use of the terms “pass” or “fail” in the test report
- Due to the definitions of Status II and III performance, the laboratory shall not make determination of compliance to immunity requirements. Verification of compliance to these requirements shall be performed via joint review of the formal test report by the FMC D&R activity and EMC department (see section 1.3).

## 7.0 Requirement Applicability

Applicability of EMC requirements is based on the E/E component category which segregates specific design characteristics for each component. E/E component categories are defined in Table 7-1. Table 7-2 lists all of the applicable EMC requirements delineated in this specification for each component category. *In some cases components may fall into multiple categories (e.g. active magnetic sensors powered from a regulato*r power supply). Under those conditions all applicable categories shall be considered. FMC EMC shall make final determination of applicability of component category and applicable requirements. The supplier shall make available relevant schematics and specifications to facilitate determination applicability of each requirement.

These requirements are applicable to both 12 and 24 VDC applications unless otherwise stated herein (e.g. CI 220 is limited to 12 VDC applications).

**Table 7-1: E/E Component Categories**

| | |
|---|---|
| **Electronic Modules** | |
| **A:** | An electronic module that contains active electronic devices. Examples: analog op-amp circuits, switching power supplies, microprocessor controllers and displays. *See section 3.0 for definition of active electronic modules.* |
| **AS:** | An electronic module operated from a regulated power supply (e.g. 3VDC, 5VDC) located in another module. This is usually a sensor providing input to a controller. The controller provides regulated power to the sensor. |
| **AM:** | An electronic module that contains magnetically sensitive elements or is connected to an external magnetically sensitive element |
| **AX:** | An electronic module that controls an inductive device (e.g., DC-Brush motors or electronically controlled motor(s), solenoids, relays, etc.) internal or external to its package. This category also includes ignition coils with integral drive electronics. |
| **AW:** | An electronic module with no external wiring (e.g. RKE Key). |
| **Electric Motors** | |
| **BM:** | A brush commutated dc electric motor with no additional electronic control |
| **EM:** | An electronically controlled brush commutated electric motor with embedded electronic control) (e.g. brushless electric motor) |
| **Other Devices** | |
| **D:** | Module or assembly containing only diodes, resistor-ladder networks, or NTCs/PTCs with or without mechanical switches (e.g., display LEDs, telltales, switches with internal backlighting LEDs, etc.). LED's which are integral to an assembly, such as a tail lamp module with integrated control electronics, are not classified as Category D devices (see Category A). |
| **R:** | Includes but not limited to Relays and solenoids |

## 7.1 ESA Type Approval

ECE Regulation 10.05 includes provisions to allow for regulatory type approval of "Electrical/electronic subassemblies (ESA). The requirements contained within this specification may be used directly to facilitate ESA Type Approval to ECE Regulation 10.05. Although most requirements contained herein exceed those of Regulation 10.05, there are specific requirements that have been included explicitly to facilitate ESA Type Approval. If ESA Type approval is not required, these selected requirements may be omitted. Table 7-2 highlights these specific requirements.

Note that ESA Type approval requires that the product is first reviewed with the appointed government authority, agree the worst case test selection and conduct those tests in a laboratory recognized by that authority and witnessed by a Technical Service. It may be possible, although not guaranteed that the relevant authority will accept test results in absence of this review and worst case selection.

The FMC D&R activity shall verify if ESA Type Approval is required for their product. If there is uncertainty about this AND if the product has been determined to contain or support any Class C or B functionality, the specific requirements for ESA Type Approval shall be applicable.

**Table 7-2: Requirement Selection Matrix**

Requirement Applies (✓)

| Requirement Type | Req. ID | Component Category: Electronic Modules | | | | | Electric Motors | | Other Devices | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A | AS | AM | AX | AW | BM | EM | D | R |
| RF Emissions | RE 310 | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓[2] | |
| | CE 420 [1] | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓[2] | ✓ [5] |
| Conducted AF | CE 421 [1] | ✓ | | ✓ | ✓ | | | ✓ | | |
| Conducted Transients | CE 410 [1] | | | | ✓ | | ✓ | ✓ | | ✓ |
| RF Immunity | RI 112 | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓[2, 3] | |
| | RI 114 | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓[2, 3] | |
| | RI 115 [6] | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓[2, 3] | |
| Magnetic Field Immunity | RI 140 | | | ✓ | | ✓ | | | | |
| Coupled Disturbances | RI 130 | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | |
| | RI 150 | ✓ | ✓ | ✓ | ✓ | | | ✓ | | |
| Continuous Disturbances | CI 210 [1] | ✓ | | ✓ | ✓ | | | ✓ | | |
| Transients | CI 220 [1] | ✓ | | ✓ | ✓ | | ✓ [8] | ✓ | ✓ | |
| | CI 221 [1,4] | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | |
| | CI 222 [1] | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | |
| Power Cycle | CI 230 [1] | ✓ | | ✓ | ✓ | | | ✓ | | |
| | CI 231 [1,4] | ✓ | | ✓ | ✓ | | | ✓ | | |
| Ground Offset | CI 250 [7] | ✓ | ✓ [7] | ✓ | ✓ | | | ✓ | | |
| Voltage Dropout | CI 260 | ✓ | ✓ | ✓ | ✓ | | | ✓ | | |
| Voltage Overstress | CI 270 [1] | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| ESD | CI 280 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ [8] | ✓ | ✓ | |

**Notes to Table 7-2:**

(1) May not be required if device is powered from a regulated or buffered supply from another module. Requires review by FMC EMC for applicability

(2) Not required if component is a mechanical switch incorporating only a simple resistor or resistor-ladder network.

(3) Requirement may be "validated by inspection" for NTCs/PTCs and devices with light emitting diodes (LED) that are used exclusively for backlighting (e.g., not used for indication of position, switch selection, etc.) provided the design has a 1- 10 nF capacitor installed across and adjacent to the NTC, PTC or LED. Requires approval by FMC EMC after a review of the electrical schematic and layout placement.

(4) Requirement applicable only for 24 VDC applications

(5) Applies to any inductive device that is pulsed at a frequency greater than 10 Hz. Contact FMC EMC department for specific applicability.

(6) RI 115 may be excluded for component categories packaged in the engine compartment

(7) CI250 is not applicable if the device has a dedicated signal return back to the controlling module AND that return is not shared by any other device.

(8) Transient overstress applied if filter components present (e.g. capacitors). May be waived with supporting analysis. Requires prior approval by FMC EMC.

## 8.0 Radiated RF Emissions: RE 310

This section pertains to limits on unintentional radio frequency (RF) radiated emissions of the DUT.

### 8.1 Requirement

Radiated emissions requirements cover the frequency range from 0.53 to 1605 MHz. Requirements are linked directly to specific RF service bands, which are segregated into Level 1 and Level 2 requirements.

Level 1 requirements listed in Table 8-1 are based on RF emissions limits from ECE Regulation 10.05

- Limit A is based on use of Average detection.
- Limit B is based on use of Quasi Peak Detection.

Level 2 requirements listed in Table 8-2 are based on specific customer requirements.

- Limit A is based on use of Peak AND Average detection for each frequency band except where noted in Table 8-2.
- Limit B is based on Quasi Peak Detection

**Exceptions to Level 2 requirements are:**

1) Feature/fucntions that operate intermittently with an active duration less than 2 seconds (longer durations require prior approval by FMC EMC
2) Feature/functions intermittently AND with direct operator control via depression of a switch.

Exception 1) requires prior review and written approval by the FMC EMC department.

Exceptions 1) and 2) above are not permitted if the device and/or its wiring are packaged within 300 mm of the vehicle's radio antennas (e.g. MW, FM, DAB, GPS).

**Table 8-1: RE 310 Level 1 Requirements**

| Band # | Frequency Range (MHz) | Limits (dBµV/m) | |
|---|---|---|---|
| | | Limit A AVG (1, 2) | Limit B QP (1) |
| M1 | 30 - 75 | 52- 25.13*Log(*f* /30) | 62 - 25.13*Log(*f* /30) |
| M2 | 75 – 400 | 42 + 15.13*Log(*f* /75) | 52 + 15.13*Log(*f* /75) |
| M3 | 400 - 1000 | 53 | 63 |

1 f = Measurement Frequency (MHz)

2 Limit A is based on use of a 120 kHz MBW with Average Detection.

**Table 8-2: RE 310 Level 2 Requirements**

| Band # | Region | RF Service (User Band in MHz) | Requirement Frequency Range (MHz) | Limits (dBµV/m) | | |
|---|---|---|---|---|---|---|
| | | | | Limit A | | Limit B |
| | | | | PK (2) | AVG (2,4) | QP (2) |
| G1 | Global | Medium Wave (AM) | 0.53 - 1.7 | 20 | 12 | 30 |
| NA1 | North America | DOT 1 (45.68 - 47.34) | 45– 48 (1) | 20 | 12 | 24 |
| G2 | Global | 4 Meter (66 – 87.2) | 65 – 88 (1) | 20 | 12 | 24 |
| JA1 | Japan | FM 1 (76 – 90) | 75 – 91 (1) | 20 | 12 | 24 |
| G3 | Global | FM 2 (87.5 – 108) | 86 – 109 (1) | 20 | 12 | 24 |
| G4 | Global | 2 Meter (142 – 175) | 140– 176 (1) | 20 | 12 | 24 |
| G5 | Global | DAB (174.1 – 240) | 172 – 242 (1) | 20 | 12 | 24 |
| G6a | Global | RKE, TPMS 1 | 310 - 320 | 20 | 14 | 30 |
| G6b | Global | RKE , TPMS 2 | 429 -439 | 25 | 19 | 30 |
| EU3 | Europe | Tetra | 380 - 430 | 20 | 14 | 30 |
| G7a | Global | RKE | 868 - 870 | 30 | 24 | |
| G7b | Global | RKE | 902 -904 | 30 | 24 | |
| G8 | Global | GPS | 1567 - 1574 | | $44 - 20664*\log(f/1567)$ (3) | |
| | | | 1574 - 1576 | | 4 | |
| | | | 1576 - 1583 | | $4 + 20782*\log(f/1576)$ (3) | |
| EU4 | Europe | GLONASS | 1598-1605 | | 4 | |

(1) User band includes 1% guard band.

(2) Limits based on detection method. AVG= Average detection, PK= Peak detection, QP = Quasi-Peak detection. See section 8.2.1 for details.

(3) f = Measurement Frequency (MHz)

(4) Average Detection limits are not applicable for components that operate with intermittent duration. Requires review/approval from FMC EMC department.

## 8.2 Test Verification and Test Setup

The requirements of CISPR 25 (2008), ALSE method, shall be used for verification of the DUT performance except where noted in this specification. Component operation during testing shall be documented in an EMC test plan prepared by the component/subsystem supplier and EMC test laboratory (see section 6.1).

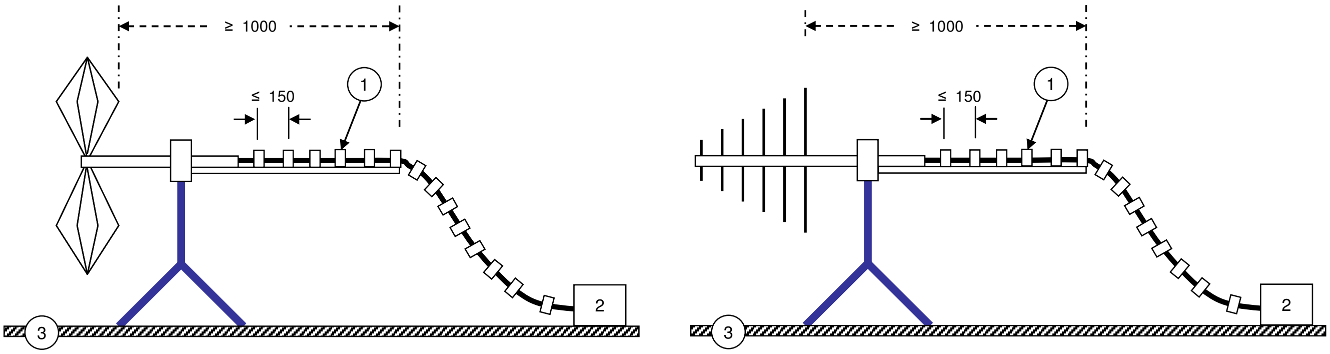
- Co-location of multiple receiving antennas in the same test chamber to support automated testing for reduced test times is not permitted.
- When performing testing using either the biconical or log antenna, the coaxial cable shall be routed directly behind the antenna as illustrated in Figure 8-1. The cable shall remain parallel to the test chamber floor for a minimum of 1000 mm behind the rear most element of the antenna (see Figure 8-1). The cable shall include ferrite beads (Fair-Rite Type 43 or equivalent) with a maximum spacing of 150 mm. Ferrite beads are not required for sections of the antenna cable lying on the test chamber floor. *The purpose for this modification is to minimize cable effects on the antenna's published antenna correction factors.*
- If a pre-amplifier is used to meet the ambient requirements (see section 8.3), the device should be located where the antenna cable meets the test chamber floor (see Figure 8-1). Location of the pre-amplifier at the antenna connector is not recommended due to possible interactions between the antenna elements and the power supply wiring to the preamplifier. The preamplifier may be located outside of the test chamber as long as the measurement system ambient requirements are met. *See section 8.2.2 for additional requirements when using preamplifiers.*
- When tests are performed above 1000 MHz, the receiving antenna shall be relocated such that its center is aligned with the center of the DUT as illustrated in Figure 15 of CISPR 25. Height of the antenna relative to the ground plane bench shall remain unchanged.
- The power supply (see section 5.5.4) shall have its negative terminal connected to the ground plane bench. The power supply may be located on, or under the test bench. The standard test setup shown in Annex F shall be used for the Load Simulator, power supply and Artificial Network. Only a single Artificial Network is used for DUT power. No Artificial Network is used for the DUT power return. The DUT power return is connected to the ground plane via the Load Simulator.
- The total harness length shall be 1700 mm (+300 /-0 mm). The harness shall lie on a dielectric support 50 mm above the ground plane. Location of the DUT and Load Simulator shall facilitate limiting the test harness bend radius to between 90 and 135 degrees as required in CISPR 25.
- The DUT shall be placed on a dielectric support 50 mm above the ground plane. However, if the outer case of the DUT is metal and, when installed in the vehicle is electrically connected to the vehicle's sheet metal, the DUT shall be mounted and electrically connected to the ground plane during the test in a manner representative of the vehicle application. *This configuration is only permitted if documented in the product's engineering specification and is representative of the vehicle application.* The DUT grounding configuration shall be documented in the EMC test plan and test report.
- For some DUT's, deviations from the standard test setup may be necessary to facilitate testing. These deviations must be reviewed and approved by the FMC EMC department prior to commencement of testing. Test setup deviations shall be documented in the EMC test plan and test report.

### 8.2.1 Measurement System Requirements

Tables 8-3, 8-4 and 8-5 list the measurement system configuration requirements.

- The measurement receiver, including those with Fast Fourier Transform (FFT capability shall be fully compliant to CISPR 16-1-1(2010). Swept receivers are no longer permitted for use. Measurement bandwidths, and detection systems used (i.e. PK, AVG, QP) shall also conform to CISPR 16-1-1 (2010) except where noted in this specification.
- Measurement dwell times listed in Tables 8-3, 8-4 and 8-5 may be increased if the DUT operates with intermittent duration; however specific rational must be documented in the EMC test plan. For Bands G1, the measurement time shall be equal to *1/f*, where *f is* the signal repetition rate. Measurement times used shall be documented in the EMC test plan.

**Figure 8-1: RE 310 Test Antenna Cable Configuration (excludes Rod antenna)**




Biconical Antenna

Log Antenna

Scale: millimeters

**Key:**

1. Ferrite Cable Bead (Fair-Rite Type 43 or equivalent)
2. Preamplifier (if required)
3. Floor of ALSE

Above 30 MHz, a low noise preamplifier is often required to meet the measurement system ambient requirements. However, use of a preamplifier will increase the potential of overload usually from out-of-band signals. To minimize this potential, it is recommended that the net gain of the pre-amplifier be selected to just meet the ambient requirements specified in section 8.3, step a). The laboratory shall also establish a procedure to avoid overload of the preamplifier, such as using a step attenuator.

**Table 8-3: RE 310 Measurement System Setup Requirements (Band G1)**

| Measurement System Parameters | Limit A | Limit B |
|---|---|---|
| **Detection Method** | Average | Quasi-Peak |
| **Measurement Bandwidth {*MBW*} (kHz)** | 9/10 (1) | 9 |
| **Frequency Step Size (kHz)** | 0.5**MBW* | 4.5 |
| **Measurement Time per Frequency Step (sec) (2)** | 0.05 | 1 |

1. MBW may be reduced to 1 kHz to meet ambient requirements in section 8.3 but only with prior written approval by FMC EMC department. Reduced MBW shall be documented in test report.
2. Measurement time may be increased for low repetition rate signals. See section 8.2.2 for details

**Table 8-4: RE 310 Measurement System Setup Requirements (All Bands except M1, M2, M3, G1)**

| Measurement System Parameters | Limit A | Limit B |
|---|---|---|
| **Detection Method** | Peak or Average | Quasi-Peak |
| **Measurement Bandwidth {*MBW*} (kHz)** | 9/10 (1); 1 (2) | 120 |
| **Frequency Step Size (kHz)** | 0.5**MBW* | 60 |
| **Measurement Time per Frequency Step (sec ) (3)** | ≥ 0.005 | 1 |

1. To allow the use of various receiver types, either bandwidth may be used
2. A 1 kHz MBW shall be used for Band G8 and EU4 . MBW deviates from CISPR 16-1-1
3. Measurement time may be increased for low repetition rate signals. See section 8.2.2 for details

**Table 8-5: RE 310 Measurement System Setup Requirements (Bands M1, M2, M3)**

| Measurement System Parameters | Limit A | Limit B |
|---|---|---|
| **Detection Method** | Average | Quasi-Peak |
| **Measurement Bandwidth {*MBW*} (kHz)** | 120 | 120 |
| **Frequency Step Size (kHz)** | 60 | 60 |
| **Measurement Time per Frequency Step (sec ) (2)** | ≥ 0.005 | 1 |

1. To allow the use of various receiver types, either bandwidth may be used
2. Measurement time may be increased for low repetition rate signals. See section 8.2.2 for details

## 8.3 Test Procedure

a) Prior to measurement of DUT radiated emissions, test setup ambient levels (i.e. all equipment energized except DUT) shall be verified to be 6 db or more below the specified requirements listed in Tables 8-1 and 8-2. If this requirement is not met, testing shall not proceed until the associated test setup issues are resolved. Plots of the test setup ambient shall be included in the test report. Test setup ambient measurements shall be performed using a 9/10 kHz MBW with peak detection except for bands G1, G8 and EU4. Band G1 requires use of quasi peak and average detection. Band s G8 and EU4 require use of a 1 kHz MBW with average detection. All test setup ambient measurements shall be performed using only vertical polarization of the measurement antenna.

b) Measurement of DUT radiated emissions shall be performed over all frequency bands listed in Tables 8-1 and 8-2. At measurement frequencies ≥ 30 MHz, measurements shall be performed in both vertical and horizontal antenna polarizations.

c) At test frequencies ≥ 1000 MHz, the DUT shall be tested in a minimum of three (3) orthogonal orientations unless otherwise stated in the EMC test plan.

d) When assessing DUT performance per Level 1 and Level 2 except bands G1, G8 and EU4, measurements may be initially performed using 120 kHz MBW with both peak (PK) and average (AVG) detection along with the other measurement system requirements delineated in Table 8-5 (Limit A). This approach facilitates reduction in the overall measurement time. If the resulting DUT AVG and PK emission levels are below the respective Limit A and Limit B limits for both Level 1 and Level 2, the test data may be submitted as the final result.

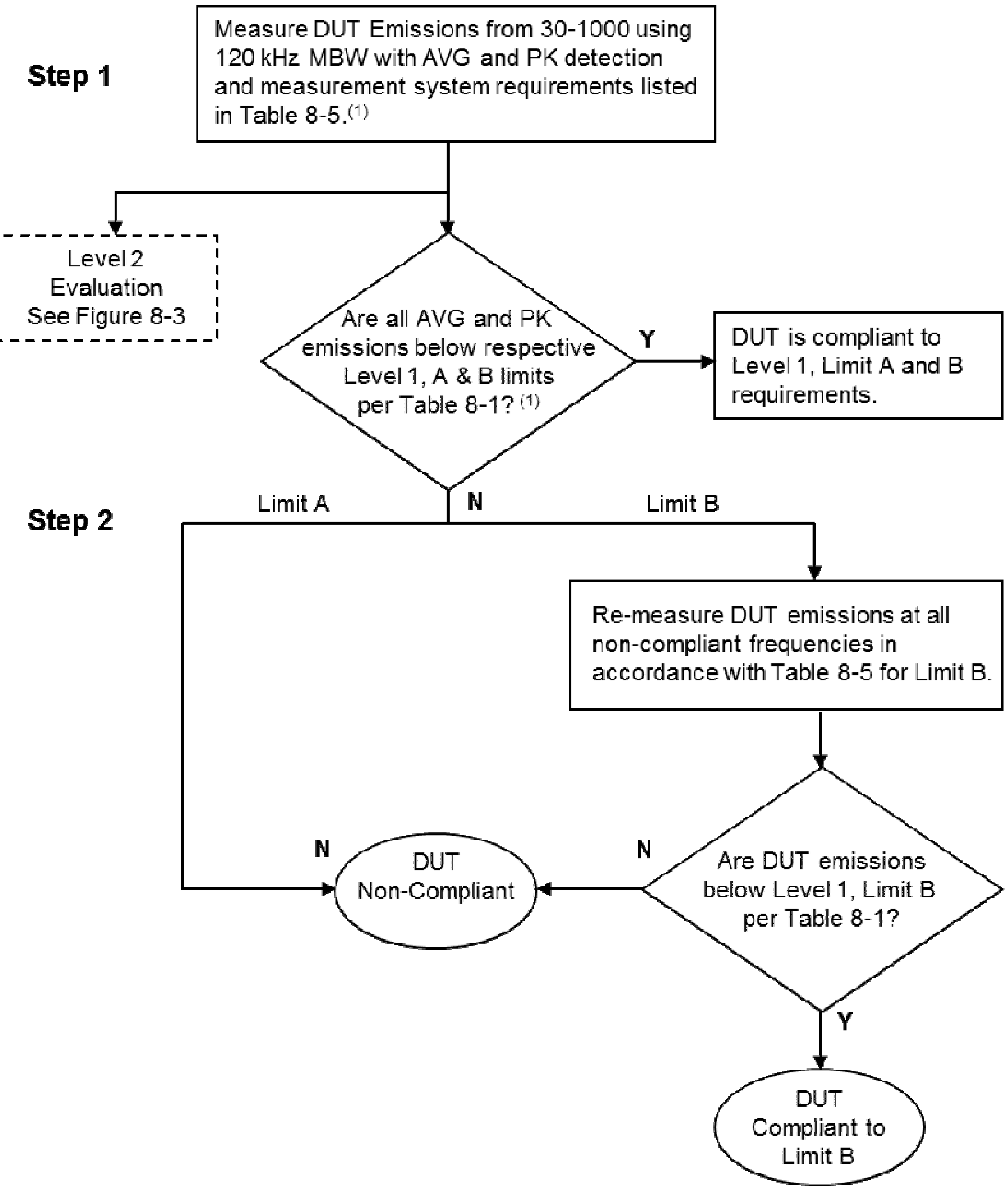
*When using 120 kHz MBW with AVG and PK detection to assess DUT emissions per Level 2, Limit A and B respectively, the test setup ambient requirements may be relaxed (per step a) such that the ambient is less than or equal to the applicable limit.*

If DUT emission levels are above any of the individual band requirements, additional measurements shall be performed using the measurement system requirements listed in Tables 8-4 and 8-5. This process is illustrated in Figures 8-2 and 8-3. Contact the FMC EMC department regarding questions and/or clarifications with respect to this process.

- When assessing compliance to Limit A (Level 2), Peak and Average measurements shall be performed over the entire frequency band(s), where the emissions from steps d) exceeded the limit. Measurements shall include both polarizations per step b).
- When assessing compliance to Limit B (Level 1 or Level 2), Quasi-Peak measurements are limited to individual frequencies where the emissions from step d) exceeded the limit. . Measurements shall include both polarizations per step b).

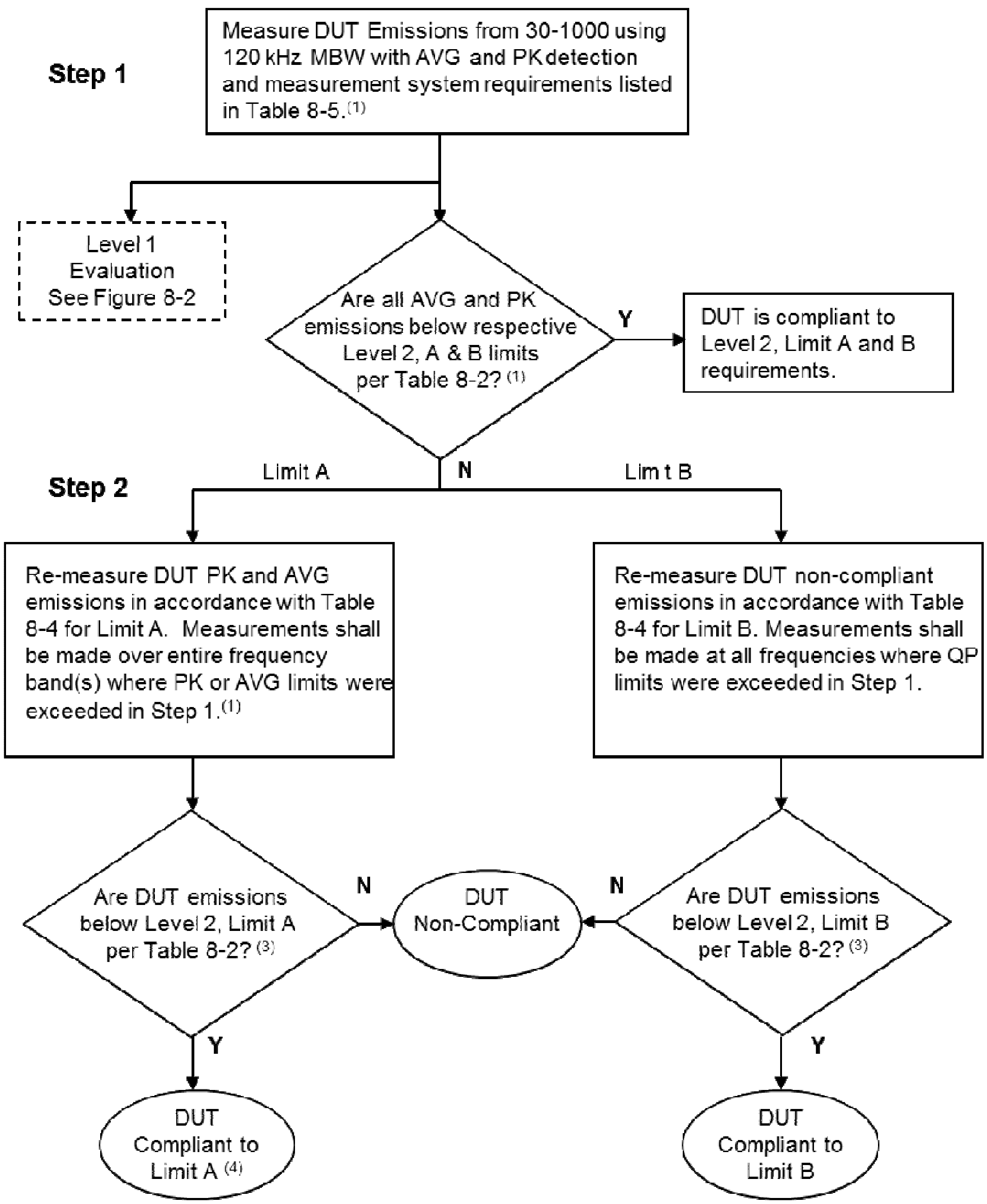
e) Tests shall be repeated for all DUT operating modes delineated in the component EMC test plan.

**Figure 8-2: Recommended Process for Assessing DUT Emissions per RE 310 Level 1 Requirements**




(1) Simultaneous PK and AVG measurements may be made using RF receivers with dual detector capability

**Figure 8-3: Recommended Process for Assessing DUT Emissions to RE310 Level 2 Requirements (Excludes Bands G1, G8, EU4)**




(1) Simultaneous PK and AVG measurements may be made using RF receivers with dual detector capability

(2) Ambient requirements (6dB) do not apply when using 120 kHz MBW, AVG and PK detection to verify Level 2, Limit A and B requirements.

(3) Measurement system and test setup ambient requirements (6dB) apply when using the MBW listed in Tables 8-3 and 8-4.

(4) Excludes bands G1, G8 and EU4

## 9.0 Conducted RF Emissions: CE 420

This section pertains to limits on unintentional radio frequency (RF) conducted emissions from the DUT power supply circuits. It also pertains to conducted emissions from any DUT regulated or buffered power circuits used to provide power to other devices.

Exceptions to these requirements are:

1) Feature/functions that operate intermittently with an active duration less than 2 seconds.
2) Feature/functions that operate intermittently AND with direct operator control via depression of a switch.
3) Components having a shielded power and power return wiring system implemented with shielded cable or by placement of multiple components in a common shielded enclosure.

Exception 1) requires prior review and written approval by the FMC EMC department.

Exceptions 1) and 2) above are not permitted if the device and/or its wiring are packaged within 300 mm of the vehicle's radio antennas (e.g. MW, FM, DAB, GPS).

Exception 3) requires prior approval by the FMC EMC department upon their review of testing and/or analysis demonstrating that the "in-vehicle" packaging will not introduce alternate paths for coupling of conducted emissions exceeding CE420 levels on to unshielded power and return circuits.

### 9.1 Requirement

Conducted RF voltage emissions on the component power and power return circuits shall not exceed the requirements listed in Table 9-1. Requirements are limited to Medium Wave (i.e. AM) and FM broadcast services.

**Table 9-1: CE 420 Conducted Emissions Requirements**

| Band # | RF Service | Frequency Range (MHz) | Limits | |
|---|---|---|---|---|
| | | | Average (dbuV) | Quasi-Peak (dbuV) |
| G1 | Medium Wave (AM) | 0.53 - 1.7 | 48 | 66 |
| JA1 | FM 1 | 76 -90 | | 36 |
| G3 | FM 2 | 87.5 - 108 | | 36 |

### 9.2 Test Verification and Test Setup

The requirements of CISPR 25 (2008), voltage method shall be used for verification of the component performance except where noted in this specification. If the DUT has separate power/power return circuits, separate tests shall be performed on each circuit. Circuits not being tested shall be connected directly to the power supply. This requirement may be waived if the multiple circuits are used only meet the operating current demands of the DUT (e.g. single power circuit, but with multiple connector pins). Under these conditions, all power circuits are connected to the Artificial Network.

- Electronic hardware in the Load Simulator shall be powered from a linear power supply (see paragraph 5.5.4 for requirements). The power supply negative terminal shall be connected to the ground plane.
- The power/power return wiring between the DUT and the Artificial Network shall be 200 +/-50 mm in length. The wiring shall be placed on a dielectric support 50 mm above the ground plane.
- Both Artificial Networks are used per CISPR 25.
- The DUT shall be placed on a dielectric support 50 mm above the ground plane. However, if the outer case of the DUT is metal and, when installed in the vehicle is electrically connected to the vehicle's sheet metal, the DUT shall be mounted and electrically connected to the ground plane during the test in a manner representative of the vehicle application. *This configuration is only permitted if documented in the product's engineering specification and is representative of the vehicle application.* The DUT grounding configuration shall be documented in the EMC test plan and test report.

- The test harness connecting the DUT shall be the same as used for RE310 testing. The harness shall be placed on an Dielectric support 50 mm above the ground plane. The test harness shall not be coiled.
- If the DUT's power return is required to be locally grounded in the vehicle within 200 mm of the DUT *(must be specified in the product's engineering specification)*, the DUT power return shall be connected directly to the ground plane at the length specified. Under these conditions, the Artificial Network connected to the DUT's power return may be omitted.
- When testing DUTs with regulated or buffered power outputs, the test setup shown in Figure 9-1 shall be used. The load resistance "R" shall be selected to achieve > 80% of the maximum power rating of the DUT output. The value of the load resistance shall be specified in the EMC test plan.

### 9.2.1 Measurement System Requirements

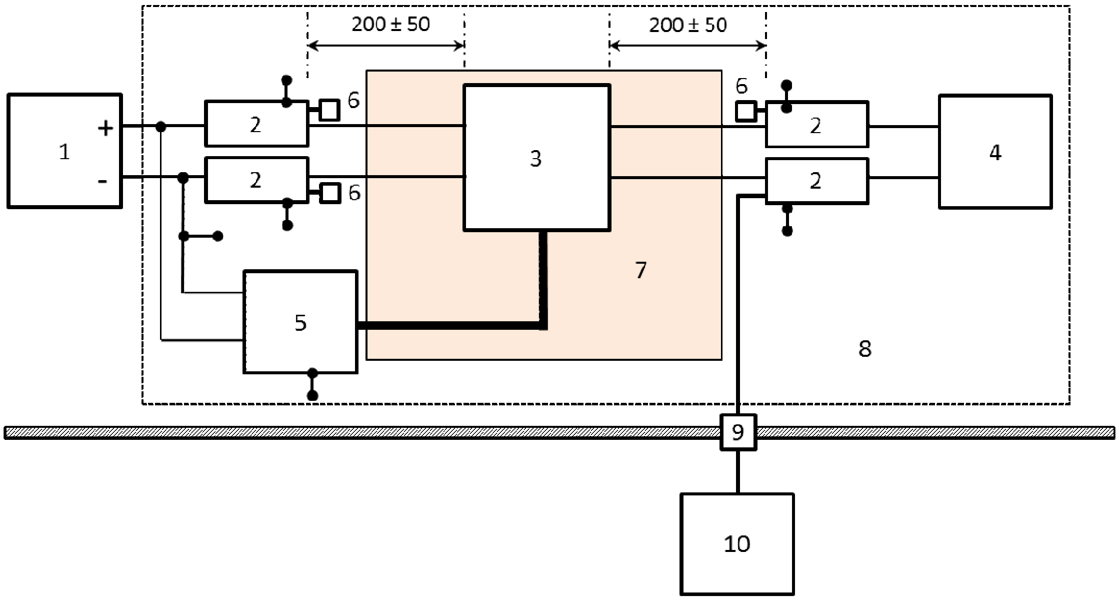
The measurement receiver, including those with Fast Fourier Transform (FFT capability shall be fully compliant to CISPR 16-1-1 as specified in CISPR 25 (2008).

Tables 8-3 and 8-4 in section 8.2.2 list the measurement system configuration requirements. Measurement dwell times listed in Tables 8-3, 8-4 and 8-5 may be increased if the DUT operates with intermittent duration, however specific rational must be documented in the EMC test plan to justify the increase. For Band G1, the measurement time shall be equal to *1/f*, where *f is* the signal repetition rate. Measurement times used shall be documented in the EMC test plan.

## 9.3 Test Procedure

a) Prior to measurement of DUT conducted emissions, test setup ambient levels (i.e. all equipment energized except DUT) shall be verified to be 6 db or more below the specified requirements listed in Table 9-1. If this requirement is not met, testing shall not proceed until the associated test setup issues are resolved. Plots of the test setup ambient shall be included in the test report. .
b) Measurement of DUT conducted emissions on both the power and power return circuits shall be performed over each frequency band listed in Table 9-1.
c) Tests shall be repeated for all DUT operating mode(s) delineated in the component EMC test plan.
d) Testing is repeated for all DUT regulated and buffered power circuits if present.
e) When assessing DUT performance to Quasi-Peak limits, the use of peak detection with the same measurement bandwidth is permitted as a quick pre-screen to increase testing efficiency. If the peak emissions are below the limit, the test data may be submitted as the final result. If the peak emissions exceed the band requirements, it will be necessary to re-sweep individual frequencies where the limit was exceeded using Quasi-peak detection. Peak and quasi-peak data shall be submitted in the test report.

**Figure 9-1 Test Setup for DUTs with Regulated or Buffered Power Outputs**




**Key:**

1. Power Supply
2. Artificial Network
3. DUT
4. Resistive Load "R" (see section 9.2)
5. Load Simulator
6. 50 ohm termination
7. Dielectric Support ($\varepsilon_r \leq 1.4$)
8. Ground Plane
9. RF bulk head connector (at shield room wall)
10. Measurement Receiver

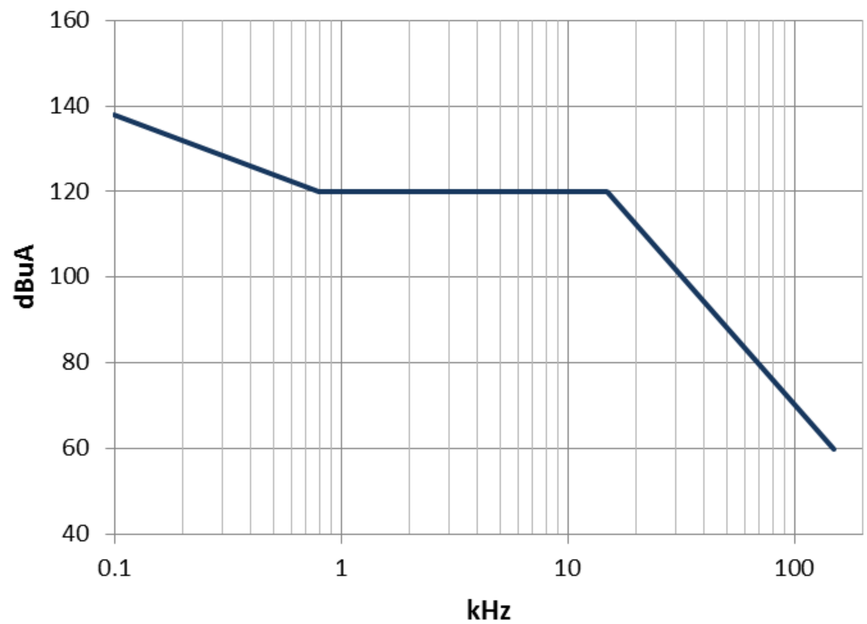
## 10.0 Conducted Emissions: CE 421

This section pertains to limits on unintentional low frequency conducted emissions on the DUT's power supply circuits.

### 10.1 Requirement

Conducted current emissions on all component power circuits shall not exceed the requirements listed in Figure 10-1.

**Figure 10-1: CE 421 Conducted Emissions Requirements**




| Frequency Range (kHz) | Limits (dBuA)* |
|---|---|
| 0.1 – 0.8 | $138 - 20Log\left(\frac{f}{0.1}\right)$ |
| 0.8 - 15 | 120 |
| 15 - 150 | $120 - 60Log\left(\frac{f}{15}\right)$ |

** f = frequency in kHz*

### 10.2 Test Verification and Test Setup

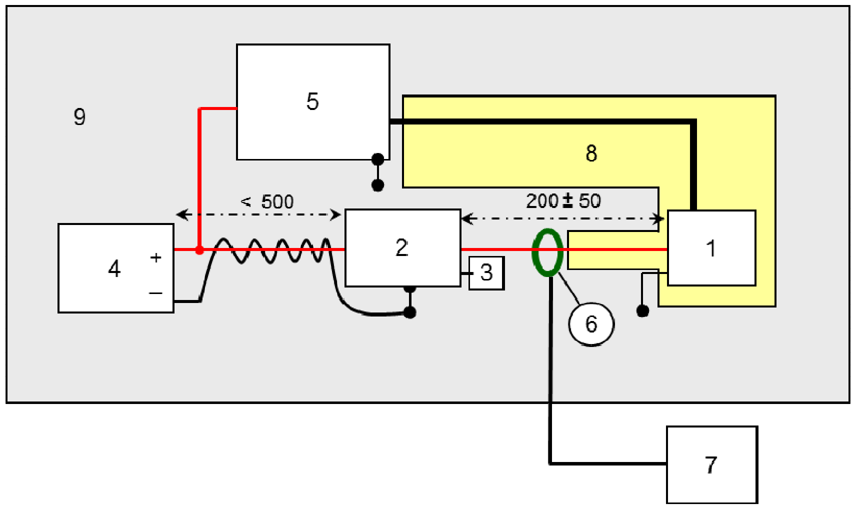
The test setup is shown in Figure 10-2. If the DUT has separate power circuits, separate tests shall be performed on each circuit. Circuits not being tested shall be connected directly to the power supply. If the DUT contains multiple circuits used only meet the operating current demands of the DUT (e.g. single power circuit, but with multiple connector pins), all power circuits shall be tied together at the artificial network.

The DUT shall be placed on a dielectric support 50 mm above the ground plane. However, if the outer case of the DUT is metal and, when installed in the vehicle is electrically connected to the vehicle's sheet metal, the DUT shall be mounted and electrically connected to the ground plane during the test in a manner representative of the vehicle application. *This configuration is only permitted if documented in the product's engineering specification and is representative of the vehicle application.* The DUT grounding configuration shall be documented in the EMC test plan and test report.

### 10.2.1 Measurement System Requirements

The measurement receiver, including those with Fast Fourier Transform (FFT capability shall be fully compliant to CISPR 16-1-1. Table 10-1 lists the measurement system configuration requirements. Typical current probe requirements are listed in Table 10-2.

**Figure 10-2: CE 421 Test Setup**




**Key:**

1. DUT
2. Artificial Network
3. Open Circuit Termination
4. Power Supply
5. Load Simulator
6. Current Probe (see Table 10-2)
7. Measurement Receiver
8. Dielectric Support ($\varepsilon_r \leq 1.4$)
9. Ground Plane

**Table 10-1: CE 421 Measurement System Setup Requirements**

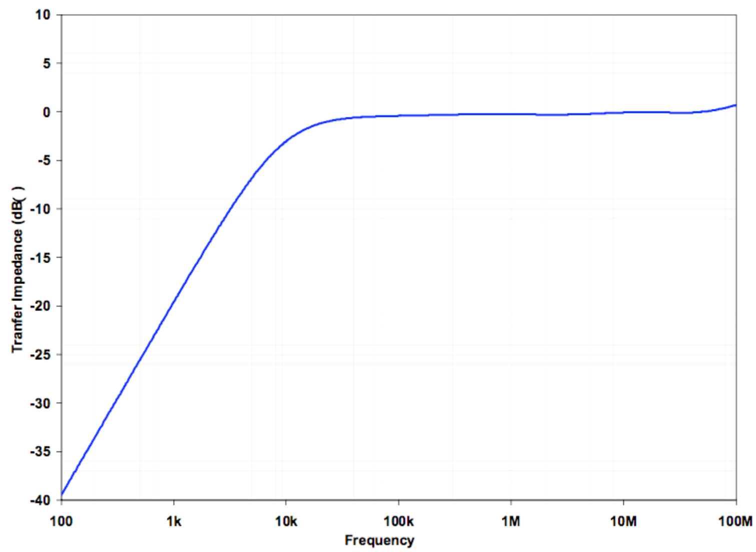
| Frequency Range (kHz) | Detector | MBW (1) (kHz) | Frequency Setup Size (kHz) | Minimum Dwell Time per Frequency Step (sec) |
|---|---|---|---|---|
| 0.1 – 1.0 | Peak | .02- .05 | 0.5**MBW* | 2.0 |
| 1.0 – 10.0 | | 0.2 - 0.5 | | 0.2 |
| 10.0 – 100.0 | | 2.0 – 5.0 | | 0.05 |
| 100.0 – 150.0 | | 9-10 | | |

(1) Use the widest available MBW in the range specified. Non CISPR MBW may be used

**Table 10-2: CE 421 Current Probe Requirements (Typical)**

| **Frequency Bandwidth** | 100 Hz – 100 MHz |
|---|---|
| Maximum Primary Current (A) DC- 400 Hz | 200 |
| Maximum Primary Current (A) RF (CW) | 3 |

**Transfer Impedance**
**(Example: FCC F35A)**




## 10.3 Test Procedure

a) Prior to measurement of DUT conducted emissions, test setup ambient levels (i.e. all equipment energized except DUT) shall be verified to be 6 dB or more below the specified requirements listed in Figure 10-1. If ambient levels are less than 6 dB below the specified limits, testing shall not proceed until the associated test setup issues are resolved. Plots of the test setup ambient shall be included in the test report.

b) Measurement of the conducted emissions from each DUT power line shall be performed over frequency range listed in Figure 10-1. Testing multiple powerlines together is not permitted.

c) Tests shall be repeated for all DUT operating mode(s) delineated in the component EMC test plan.

## 11.0 Conducted Transient Emissions: CE 410

This section pertains to limits on conducted transient emissions from the DUT power supply circuits.

These requirements are related to conducted transients from the DUT switched power supply circuits when power is removed.

### 11.1 Requirement

The component shall not produce transient voltages magnitudes exceeding those shown in Table 11-1. Compliance to this requirement by the individual component may be waived if it can be demonstrated it derives its power from another module. However, the resulting subsystem is required to comply with these requirements. Contact FMC EMC department for guidance.

**Table 11-1: Transient Voltage Emission Limits**

| Polarity of Pulse Amplitude | 12 VDC systems | 24 VDC systems |
|---|---|---|
| Positive | +75 | +150 |
| Negative | −100 | −450 |

### 11.2 Test Verification and Test Setup

The DUT shall be tested in accordance with ISO 7637-2 (2004), except where noted in this specification, using the test setup illustrated in Figure 11-1.

- Each DUT power circuit shall be connected directly to separate Artificial Networks through either a mechanical or electromechanical switch with a single set of contacts. Untested circuits shall be directly connected to the power supply. The switch shall have the following characteristics:
  - Contact rating: $I \geq 30$ A or twice the rated current of the DUT (whichever is greater), continuous, resistive load .
  - No suppression across relay contact;
  - Single/double position contact electrically insulated from the coil circuit
  - Coil with transient suppression *(applies only to electromechanical relay)*

  The actual switch used for testing shall be specified in the EMC test report.
- The wiring between the DUT and the Artificial Network shall be 200 +/-50 mm in length. No other connections shall be made between the switch and the DUT.
- The supply voltage to the DUT shall be (+15 -0.5/+0) or (+26.5 -0.5/+0) volts for 12 and 24 VDC tests respectively. The power supply shall have a short circuit current capability 100 amperes or twice the specified stall current of the DUT. The negative terminal of the power supply shall be connected to the ground plane.
- A digital sampling scope shall be used for the voltage measurements using a capable sampling rate of 1 Giga-samples per second (single acquisition capability) and a minimum memory depth of 2048 samples. The bandwidth shall be greater than 100 MHz. The voltage shall be measured using a 1:100 probe (< 4 pf). See ISO 7637-2 for additional requirements
- The DUT shall be placed on a dielectric support 50mm above the ground plane. A DUT with an outer metal chassis may be electrically connected to the ground plane only if the DUT's design requires that its chassis must be grounded to the vehicle for functionality (*the DUT engineering specification must state this requirement*). The DUT's grounding configuration shall be documented in the EMC test plan and test report.
- If the DUT is an electric motor or actuator, it shall be tested in the "stall" condition unless analysis demonstrates this condition cannot occur. If the motor contains internal protection (e.g. PTC device) that would limit or interrupt current to the DUT during a stall condition, testing shall be performed with the maximum rated mechanical load on the motor/actuator.

## 11.3 Test Procedures

a) Close the external switch and power up the DUT. Verify the DUT is functioning properly.

b) Set the oscilloscope time base to 1 msec/div.

c) Set the oscilloscope for single acquisition mode ("single shot"). Set the trigger level to +10 volts.

d) Open and close the external switch contacts to verify the scope properly triggers. Do not proceed until triggering has been verified!

e) With the DUT active, set to oscilloscope trigger level to 80% of the positive limit (e.g. +60V for 12VDC systems). Adjust the oscilloscope sampling rate to the highest level available for the time base selected.

f) If the DUT is of component categories AX, AY and EM, monitor the oscilloscope for any detection of transient voltages exceeding the trigger level from step e) while exercising the DUT functions in operating modes identified in the EMC test plan. Document the associated functions causing these transient events. *Note: Step f) may be omitted for component categories BM and R.*

g) For all component categories with switched power circuits, monitor the oscilloscope for any detection of transient voltages exceeding the trigger level from step e) while cycling the DUT power circuit off and on ten times via the external switch shown in Figure 11-1.

h) If transient events are detected in steps f) or g) at the trigger level set in step e)

- Repeat exercising the associated DUT function from step f) while making small increases in the magnitude of the oscilloscope trigger level. Continue this adjustment until the oscilloscope will no longer will trigger. Reduce the trigger level slowly while exercising the same DUT function. When the scope triggers, record the transient waveform including its peak positive transient voltage.
- Repeat cycling the DUT power circuit while making small increases in the magnitude of the oscilloscope trigger level. Continue this adjustment until the oscilloscope will no longer will trigger. Reduce the trigger level slowly while exercising the same DUT function. When the scope triggers, record the transient waveform including its peak positive transient voltage.

i) If no events are captured during step h), reduce the oscilloscope trigger level until a transient event is observed. Capture and record the transient event along with the trigger level.

j) Repeat step e) through i) for each of the following time base values:

- 100 usec/div;
- 1 usec/div

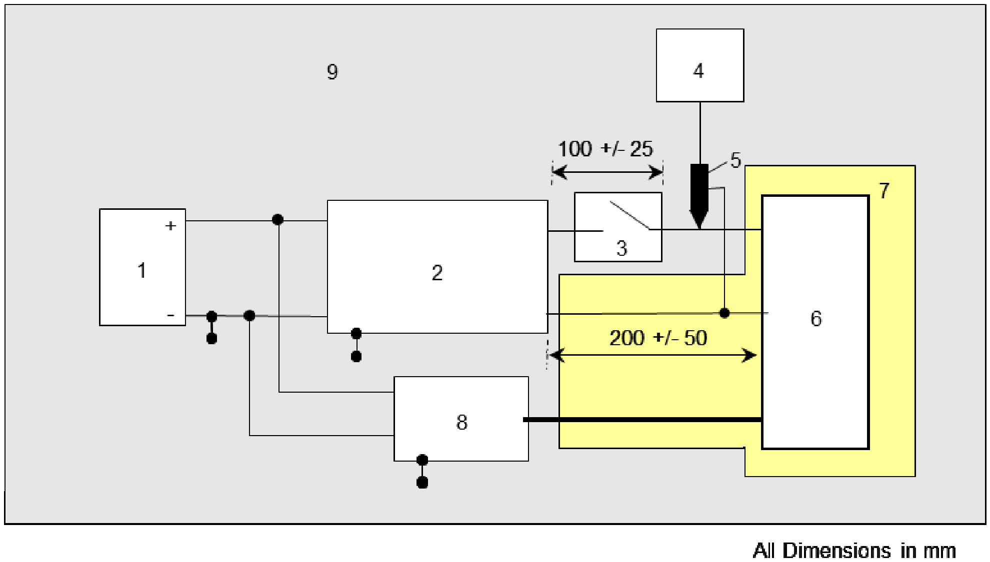
*Alternative time base values may be selected if those listed are not available for the oscilloscope used. The lab shall use the closest time base value available. The time bases used shall be documented in the EMC test report.*

k) Re-adjust the trigger level of the digital sampling scope to 80% of the negative limit (e.g. -80V for 12 VDC systems). Repeat steps e) through j) except record the peak negative transient voltages exceeding the trigger level.

***Design Note***

*Although CE 410 requirements are validated at room temperature, the product should be designed to meet the same requirements at -45 degrees C or the coldest ambient temperature specified in the product's engineering specification.*

**Figure 11-1: CE 410 Transient Emissions Test**




**Key:**

1. Power Supply (see 11.2 for voltage setting)
2. Artificial Network (AN)
3. Mechanical /Electromechanical Switch
4. Digitizing Oscilloscope
5. High Impedance Probe (1:100, C < 4pf. See ISO 7637-2) *Example: Agilent 10076A*
6. DUT
7. Dielectric support ($\varepsilon_r \leq 1.4$)
8. Load Simulator
9. Ground Plane

## 12.0 RF Immunity: RI 112, RI 114, RI 115

This section pertains to immunity of the DUT to radiated RF disturbances produced from on-vehicle RF sources (e.g. amateur radio, cellular phones) and/or off vehicle RF sources (mobile/fixed land base radios, radars). Radiated immunity requirements cover the frequency range from 1 to 3100 MHz

### 12.1 Generic Requirements

Component functional performance shall meet the acceptance criteria delineated in Table 12-1. Due to the wide frequency coverage, multiple test methods are needed for performance verification. Level 1 and Level 2 requirements are dependent on those test methods.

**Table 12-1: RF Immunity Acceptance Criteria**

| Requirement Level | Functional Performance Status (1) | | |
|---|---|---|---|
| | **Class A** | **Class B** | **Class C** |
| 1 | I (1) | I (1) | I (1) |
| 2 | II | II | I (1) |

(1) Wireless RF functions may exhibit Status II response when exposed to disturbances within the same operating bandwidth as the function. Specific requirements shall be defined within the EMC test plan

### 12.2 Generic Test Setup

- See Annex F regarding the standard test setup for the Load Simulator, power supply and Artificial Network.
- The DUT wire harness shall be 1700 mm (+ 300/- 0 mm) long. The harness shall be routed 50 mm above the ground plane (excludes RI 114 bands 7 and 8) on a dielectric support ($\varepsilon_r \leq 1.4$) over the entire length between the DUT and the Load Simulator. .
- Excluding RI114 (bands 7 and 8), the DUT shall be placed on a dielectric support ($\varepsilon_r \leq 1.4$) 50 mm above the ground plane. If the outer case of the DUT is metal and, when installed in the vehicle is electrically connected to the vehicle's sheet metal, the DUT shall be mounted and electrically connected to the ground plane during the test in a manner representative of the vehicle application. *This configuration is only permitted if documented in the product engineering specification and is representative of the vehicle application.* The DUT grounding configuration shall be documented in the EMC test plan and test report.
- Excluding RI114 (bands 7 and 8), the power supply (see section 5.5.4) shall have its negative terminal connected to the ground plane bench. The power supply may be located on, or under the test bench. The standard test setup shown in Annex F shall be used for the Load Simulator, power supply and Artificial Network. Only a single Artificial Network is used for DUT power. No Artificial Network is used for the DUT power return. The DUT power return is connected to the ground plane via the Load Simulator.
- When performing testing per RI114, (bands 7 and 8) the DUT shall be placed directly on a dielectric support ($\varepsilon_r \leq 1.4$) with no ground plane (see sections 12.6.1.2 and 12.6.1.3). If the outer case of the DUT is metal and, when installed in the vehicle is electrically connected to the vehicle's sheet metal, a braided copper ground strap shall be used to connect the DUT case to the battery negative terminal. The strap shall be 1700 mm (+300/- 0 mm) with a width no greater than 13 mm. The strap shall be co-routed with the test harness. This method shall also be used if the DUT power returns require local grounding.
- When using pulse modulations, either peak envelope power (PEP) sensors or a spectrum analyzer are required to measure forward power however use of PEP sensors are preferred. If the spectrum analyzer is used, it shall be tuned to each individual frequency using zero span setting with a measurement bandwidth greater than or equal to 3 MHz (for both the resolution or IF bandwidth and the video bandwidth, if applicable). The same type of measurement device shall be used during both calibration and test. Alternative methods are not permitted.

## 12.3 Generic Test Procedures

- All RF Immunity testing (RI 112, RI114, RI 115) shall be performed using the test frequencies listed in Tables 12-2, 12-3, and 12-4.
- Peak conservation shall be used per ISO 11452- 1(≥ 2005). CW and modulation (AM & Pulsed) dwell times shall be a minimum of 2 seconds. Longer dwell times may be necessary if DUT function response times are expected to be longer. This information shall be documented in the EMC test plan.
- Amplifier output harmonics content shall conform to the requirements of ISO 11452-1 (≥ 2005). Field modulation and leveling shall conform to the requirements delineated in Annex B.
- The AM modulation frequency shall be 1 kHz at a level of 80%.
- Testing shall be initially performed using Level 2 requirements. If deviations or anomalies are observed, the stress level shall be reduced until the DUT deviation or anomaly disappears. The stress level shall then be increased by steps less than 1 dB until the deviation or anomaly reappears. The stress level at this point shall be verified to meet the performance requirements delineated in Table 12-1. This level shall be reported as the deviation threshold.
- The DUT shall be monitored for any/all deviations during the entire RF cycle, including all modulation types and dwell times, unless otherwise specified in the test plan. If deviations are observed, the field shall be reduced until the DUT functions normally. The field shall then be increased until the deviation occurs. This level shall be reported as deviation threshold. See Annex B for leveling and threshold requirements. Separate deviation threshold plots are required for each deviation type observed during the test.

## 12.4 Alternative Test Procedures

Alternative test methods beyond those delineated within this specification are not permitted except where noted in this specification or where alternative methods may be required to accommodate unique functional aspects the component and/or subsystem. These unique test conditions shall be only be used with prior approval by the FMC EMC department and fully documented in the approved EMC test plan (see section 6.1).

**Table 12-2: RF Immunity Test Frequencies: Bands 1 – 4 ( 1 – 400 MHz )**

| Band 1 | Band 2 | Band 3 | | Band 4 | | | |
|---|---|---|---|---|---|---|---|
| 1.00 | 2.20 | 15.74 | 37.49 | 62.37 | 122.77 | 181.82 | 277.47 |
| 1.10 | 2.42 | 16.51 | 38.26 | 64.19 | 125.6 | 184.51 | 281.66 |
| 1.22 | 2.66 | 17.32 | 39.04 | 66.07 | 128.49 | 187.23 | 285.91 |
| 1.35 | 2.92 | 18.17 | 39.84 | 68.00 | 131.45 | 190.00 | 290.22 |
| 1.49 | 3.21 | 19.06 | 40.66 | 69.41 | 134.48 | 192.81 | 294.60 |
| 1.64 | 3.53 | 20 | 41.49 | 70.85 | 137.58 | 195.65 | 299.05 |
| 1.81 | 3.88 | 21.04 | 42.34 | 72.32 | 140.76 | 198.54 | 303.56 |
| 2.00 | 4.27 | 22.13 | 43.21 | 73.82 | 144.00 | 201.47 | 308.14 |
| | 4.69 | 23.28 | 44.09 | 75.35 | 145.44 | 204.45 | 312.79 |
| | 5.15 | 24.49 | 45.00 | 76.92 | 146.90 | 207.47 | 317.50 |
| | 5.67 | 25.77 | 45.92 | 78.51 | 148.37 | 210.53 | 322.29 |
| | 6.23 | 27.11 | 46.86 | 80.14 | 149.85 | 213.64 | 327.16 |
| | 6.85 | 28.52 | 47.82 | 81.80 | 151.35 | 216.8 | 332.09 |
| | 7.53 | 30.00 | 48.80 | 83.50 | 152.87 | 220.00 | 337.10 |
| | 8.28 | 30.61 | 49.79 | 85.23 | 154.40 | 222.49 | 342.19 |
| | 9.10 | 31.24 | 50.81 | 87.00 | 155.94 | 225.00 | 347.35 |
| | 10.00 | 31.88 | 51.85 | 89.46 | 157.50 | 228.39 | 352.59 |
| | 10.52 | 32.53 | 52.92 | 91.98 | 159.08 | 231.84 | 357.91 |
| | 11.07 | 33.20 | 54.00 | 94.58 | 160.67 | 235.34 | 363.31 |
| | 11.64 | 33.88 | 55.44 | 97.25 | 162.28 | 238.89 | 368.79 |
| | 12.25 | 34.57 | 56.92 | 100.00 | 163.91 | 242.49 | 374.35 |
| | 12.88 | 35.28 | 58.44 | 102.31 | 165.55 | 246.15 | 380.00 |
| | 13.55 | 36.00 | 60.00 | 104.66 | 167.20 | 249.86 | 384.07 |
| | 14.26 | 36.74 | | 107.08 | 168.88 | 253.63 | 388.18 |
| | 15.00 | | | 109.54 | 170.57 | 257.46 | 392.34 |
| | | | | 112.07 | 172.28 | 261.34 | 396.54 |
| | | | | 114.65 | 174.00 | 265.29 | 400.00 |
| | | | | 117.30 | 176.57 | 269.29 | |
| | | | | 120.00 | 179.18 | 273.35 | |

**Table 12-3: RF Immunity Test Frequencies: Bands 5 – 8 ( 380 – 3100 MHz )**

| Band 5 | | Band 6 | | Band 7 | Band 8 |
|---|---|---|---|---|---|
| 360.00 | 527.72 | 806.00 | 1233.6 | 1200.00 | 2700.00 |
| 364.90 | 535.77 | 814.9 | 1252.36 | 1213.29 | 2734.12 |
| 369.86 | 543.93 | 823.9 | 1271.42 | 1226.72 | 2768.68 |
| 374.90 | 552.22 | 833.01 | 1290.76 | 1240.30 | 2803.67 |
| 380.00 | 560.64 | 842.21 | 1310.4 | 1254.03 | 2839.10 |
| 384.07 | 569.18 | 851.51 | 1330.34 | 1267.92 | 2874.98 |
| 388.18 | 577.86 | 860.92 | 1350.58 | 1281.95 | 2911.32 |
| 392.34 | 586.66 | 870.43 | 1371.13 | 1296.15 | 2948.11 |
| 396.54 | 595.60 | 880.04 | 1391.99 | 1310.50 | 2985.37 |
| 400.78 | 604.68 | 889.76 | 1413.17 | 1325.01 | 3023.10 |
| 405.07 | 613.90 | 899.59 | 1434.67 | 1339.68 | 3061.31 |
| 409.41 | 623.25 | 909.53 | 1456.5 | 1354.51 | 3100.00 |
| 413.79 | 632.75 | 919.57 | 1478.66 | 1369.51 | |
| 418.22 | 642.40 | 929.73 | 1501.16 | 1384.67 | |
| 422.70 | 652.19 | 940.00 | 1524.00 | 1400.00 | |
| 427.22 | 662.13 | 954.3 | 1547.19 | | |
| 431.80 | 672.22 | 968.82 | 1570.73 | | |
| 436.42 | 682.46 | 983.56 | 1594.63 | | |
| 441.09 | 692.86 | 998.53 | 1618.89 | | |
| 445.81 | 703.42 | 1000.00 | 1643.52 | | |
| 450.58 | 714.14 | 1013.72 | 1668.53 | | |
| 455.41 | 725.03 | 1029.14 | 1693.91 | | |
| 460.28 | 736.07 | 1044.8 | 1719.69 | | |
| 465.21 | 747.29 | 1060.7 | 1745.85 | | |
| 470.19 | 758.68 | 1076.84 | 1772.42 | | |
| 475.22 | 770.24 | 1093.22 | 1799.38 | | |
| 480.31 | 781.98 | 1109.86 | 1826.76 | | |
| 485.45 | 793.90 | 1126.74 | 1854.56 | | |
| 490.65 | 806.00 | 1143.89 | 1882.77 | | |
| 495.90 | | 1161.29 | 1911.42 | | |
| 501.21 | | 1178.96 | 1940.5 | | |
| 506.58 | | 1196.9 | 1970.03 | | |
| 512.00 | | 1215.11 | 2000.00 | | |
| 519.80 | | | | | |

**Table 12-4: RF Immunity Test Frequencies: Bands 9 – 14 ( 380 – 2700 MHz )**

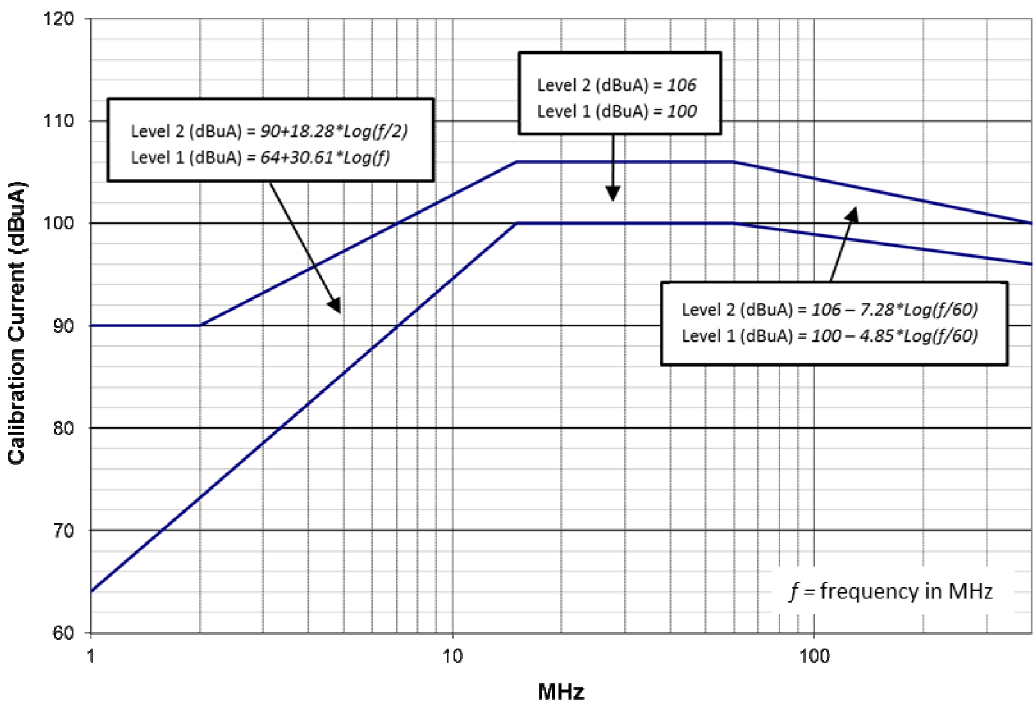
| Band 9 | Band 10 | Band 11` | Band 12 | Band 13 | Band 14 |
|---|---|---|---|---|---|
| 360.00 | 800.00 | 1600.00 | 1950.00 | 2400.00 | 2500.00 |
| 364.90 | 808.55 | 1617.68 | 1971.50 | 2424.62 | 2527.64 |
| 369.86 | 817.18 | 1635.56 | 1993.24 | 2449.49 | 2555.58 |
| 374.90 | 825.91 | 1653.63 | 2015.22 | 2474.62 | 2583.83 |
| 380.00 | 834.74 | 1671.91 | 2037.44 | 2500.00 | 2612.40 |
| 384.25 | 843.65 | 1690.38 | 2059.91 | | 2641.28 |
| 388.55 | 852.67 | 1709.06 | 2082.62 | | 2670.48 |
| 392.90 | 861.77 | 1727.95 | 2105.58 | | 2700.00 |
| 397.29 | 870.98 | 1747.05 | 2128.80 | | |
| 401.74 | 880.28 | 1766.35 | 2152.27 | | |
| 406.23 | 889.69 | 1785.87 | 2176.01 | | |
| 410.77 | 899.19 | 1805.61 | 2200.00 | | |
| 415.37 | 908.80 | 1825.56 | | | |
| 420.02 | 918.51 | 1845.74 | | | |
| 424.71 | 928.32 | 1866.13 | | | |
| 429.47 | 938.23 | 1886.75 | | | |
| 434.27 | 948.26 | 1907.61 | | | |
| 439.13 | 958.39 | 1928.69 | | | |
| 444.04 | 968.63 | 1950.00 | | | |
| 449.01 | 978.97 | | | | |
| 454.03 | 989.43 | | | | |
| 459.11 | 1000.00 | | | | |
| 464.25 | | | | | |
| 469.44 | | | | | |
| 474.69 | | | | | |
| 480.00 | | | | | |

## 12.5 Requirements 1 -400 MHz: RI 112

The device shall operate as specified in Figure 12-1 when exposed to the RF current levels and modulation listed and illustrated in Figure 12-1. The currents are produced using the BCI test method.

*RI 112 cannot be used for component category AW (no wire harness). Alternative methods may be used (e.g. TEM cell), but only with prior authorization by the FMC EMC department. The test method used, including test setup detail shall be documented in the approved EMC test plan.*

**Figure 12-1: RI 112 Requirements using Bulk Current Injection (BCI)**




| Band | Frequency Range (MHz) | Level 1 (dBµA) | Level 2 (dBµA) | Modulation |
|---|---|---|---|---|
| 1 | 1 – 2 | 64 – 73.2 | 90 | CW, AM 80% |
| 2 | 2 - 15 | 73.2 - 100 | 90 – 106 | CW, AM 80% |
| 3 | 15 - 60 | 100 | 106 | CW, AM 80% |
| 4 | 60 – 400 | 100 - 96 | 106 - 100 | CW, AM 80% |

### 12.5.1 Test Verification and Test Setup

Verification of component performance shall be in accordance with the BCI (substitution method) per (ISO 11452-4) except where delineated in this specification.

- The test bench shall include a sufficiently large ground plane, such that the test harness lies in a straight line. Spacing between the edge of the ground plane and the test harness, DUT, Load Simulator etc. shall conform to ISO 11452-4.
- The distance between the test setup and all other conductive structures (such as the walls of the shielded enclosure) with the exception of the ground plane shall be ≥ 500 mm.
- The injection probe shall be limited to single turn primary (e.g. FCC F-140). The probe calibration fixture shall be from the same manufacture and designed specifically for use with the probe selected.
- In the frequency range from 1 MHz to 60 MHz all power return (i.e. ground) wires of the DUT wiring harness shall be terminated directly to the ground plane (DBCI) as illustrated in Figure 12-2a**.** The length of the wiring shall be 200 ± 50 mm. No power return wiring shall be routed around the BCI injection probe. The power return wiring may be left in the injection probe if the power and power return wiring are twisted or are part of a shielded multi-conductor cable (e.g. LVDS). These special characteristics must be specified in the product's engineering specification and reviewed/approved by the FMC EMC department. These special characteristics shall be documented in the EMC test plan.
- In the frequency range 20 MHz to 400 MHz all wires of the DUT wiring harness shall be routed inside of the injection probe (CBCI) as illustrated in Figure 12-2b.
- If the DUT has multiple connectors, testing (DBCI, CBCI) shall be repeated from 1 to 400 MHz with the injection probe placed around the individual harness wiring associated with each individual DUT connector. Circuits contained in each harness shall be documented in the EMC test plan. Untested harness wiring shall remain bundled with the harness wiring under test. In the location of the injection probe, the untested wiring shall be routed around the outside of the probe. The untested wiring shall remain as close as possible to the outer case of the injection probe.
- The injection probe shall be insulated from the ground plane.
- An optional current monitoring probe may not be used unless first approved by FMC prior to commencement of testing and documented in the EMC test plan. If the probe is used, it shall be placed 50 mm from the DUT. The monitor probe shall be insulated from the ground plane.

### 12.5.2 Test Procedure

a) Use the calibrated injection probe method (substitution method) according to ISO 11452-4. For calibration and during the actual test of a DUT, forward power shall be used as reference parameter.

b) Use the test frequencies listed in Table 12-2 and the modulation as specified in Figure 12-1.

c) Testing shall be performed using DBCI and CBCI as illustrated in Figure 12-3.

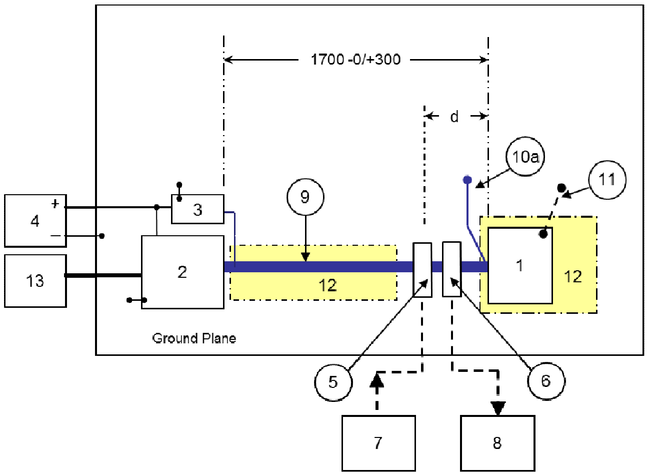
- DBCI shall be performed over the frequency range from 1 to 60 MHz, using two fixed injection probe positions (**150 mm, 450 mm**).
- CBCI shall be performed over the frequency range from 20 MHz to 400 MHz, using three fixed injection probe positions (**150mm**, **450 mm, 750 mm**). *Note that the 150 mm position may be omitted if ESA type approval per ECE Regulation 10.05 is not required (see section 7.1)*

d) Repeat testing for each harness connected to the DUT.

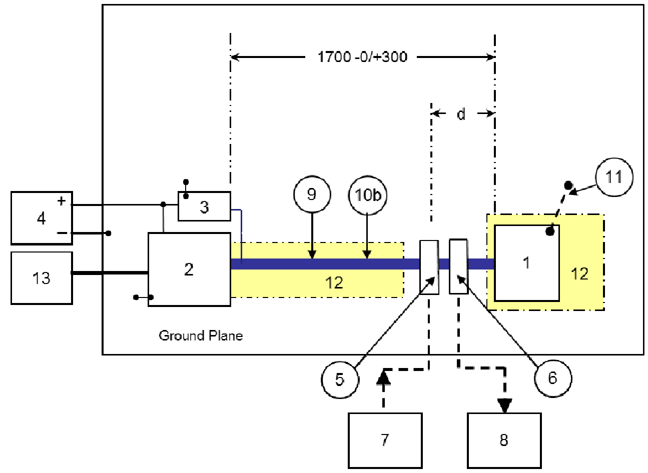
e) The DUT operating mode(s) exercised during testing shall conform to that delineated in the EMC test plan.

f) If a monitor probe is used during testing, it shall not be used to adjust the RF current delineated in Figure 12-1. The measured values are used for information only and may be included, but are not required, in the test report.

**Figure 12-2: RI 112 DUT Harness Configurations**




**(a) DBCI**




**(b) CBCI**

Key:

1. DUT
2. Load Simulator
3. Artificial Network
4. Power Supply
5. Injection Probe
6. Monitor Probe (requires prior approval by FMC EMC approval to use).
7. RF Generation Equipment
8. Current Monitoring Equipment
9. DUT Wire harness

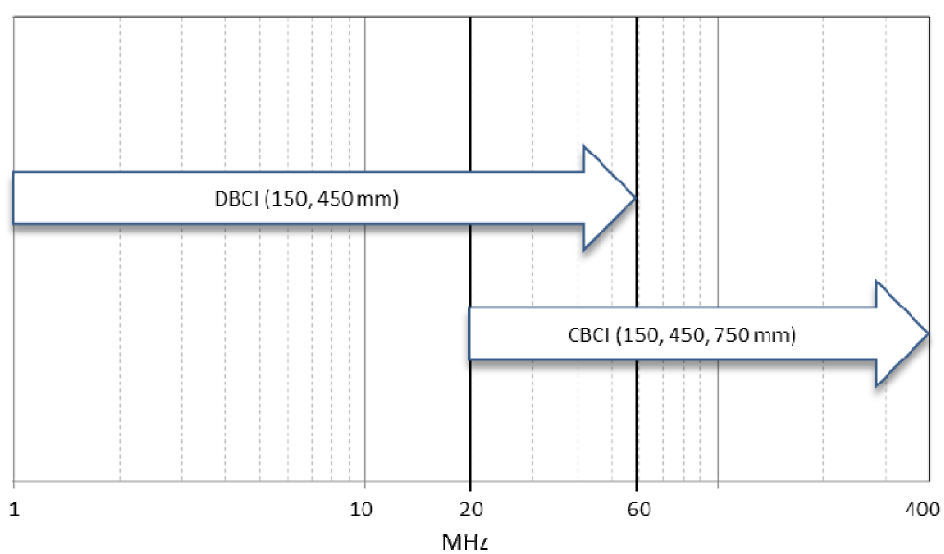
10a. DUT Power Return removed from wire harness and connected directly to sheet metal. Wire length is 200 ±50 mm.

10b. DUT Power Return included in DUT wire harness

11. DUT Case Ground (see section 12.2)
12. Dielectric Support ($\varepsilon_r \leq 1.4$)
13. Support/Monitoring Equipment

**d= Injection probe distance from DUT (see section 12.4.2)**

**Figure 12-3: Application of DBCI and CBCI**






October 07, 2016

## 12.6 Requirements: 360 – 3100 MHz: RI 114

The device shall operate as specified in Table 12-1 when exposed to RF electromagnetic fields as delineated in Table 12-5.

**Table 12-5: RI 114 Requirements ( 400 – 3100 MHz )**

| Band | Frequency Range (MHz) | Level 1 (V/m) | Level 2 (V/m) | Modulation |
|---|---|---|---|---|
| 5 | 360 - 806 | 50 | 100 | CW, AM 80%<br>PM PRR= 18 Hz, PD= 28 msec (1) |
| 6 | 806 - 2000 | 50 | n/a | CW, PM: PRR= 217 Hz, PD= 576 usec |
| 7 | 1200 - 1400 | n/a | 300<br>600 (2) | PM PRR= 300 Hz, PD= 3 usec (3)<br>with only 50 pulses output every 1 sec |
| 8 | 2700 – 3100 | n/a | 300<br>600 (2) | |

1. Pulse Modulation limited to 400 – 470 MHz. CW and AM modulation apply over the entire band (360 – 806 MHz).
2. 600 V/m requirements are only applicable to selected components associated with supplemental restraints system including frontal crash sensors. Contact FMC EMC department for specific applicability
3. Pulse duration (PD) shall be extended to 6 usec when testing using the reverberation (mode tuned) method. See 12.6. 2.2 for additional detail.

### 12.6.1 Test Verification and Test Setup

Verification of device performance shall be in accordance with either the following methods:

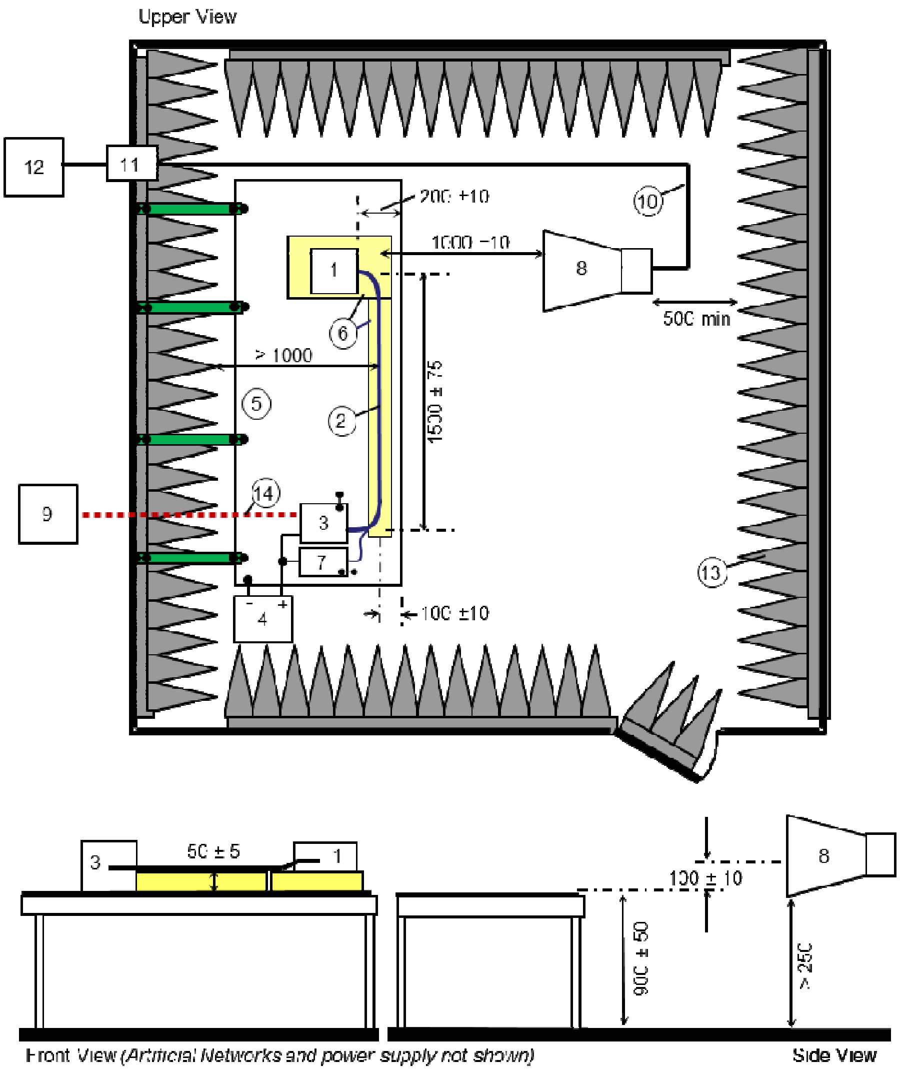
- ALSE Method (ISO 11452-2) except where noted in this specification.
- Reverberation, (Mode Tuned) Method (IEC 61000-4-21) except where noted in this specification the reverberation method is the preferred method therefore shall always be used when available.

  *Note: Reverberation method is not normally used for DUTs that contain an RF receiver as part of their design (e.g., infotainment radio, RFA/RKE Receiver, etc.) Contact the FMC EMC department for guidance.*

#### 12.6.1.1 ALSE Method (Bands 5 and 6)

- The test setup conforms to that illustrated in ISO 11452-2 except that only one artificial network is used. See Annex F for additional detail on use of the artificial network. The setup is similar to that use for RE310. Location of the DUT and Load Simulator shall facilitate limiting the test harness bend radius to between 90 and 135 degrees
- For frequencies ≤ 1000 MHz, the field-generating antenna shall be positioned in front of the middle of the harness. For frequencies above 1000 MHz, the antenna shall be moved 750 mm parallel to the front edge of the ground plane towards the DUT. The center of the antenna shall be pointed directly at the DUT instead of the center of the wiring harness (See Figure 12-4). Calibration procedures shall be performed in accordance with ISO 11452-2.

**Figure 12-4: RI 114 ALSE Test Setup for Testing Above 1000 MHz**




**Key:**

1. DUT
2. Wire Harness
3. Load Simulator
4. Power Supply
5. Ground Plane (bonded to shielded enclosure)
6. Dielectric Support (($\varepsilon_r \leq 1.4$)
7. Artificial Network
8. Transmitting Antenna
9. Support/Monitoring Equipment
10. Double Shielded Coaxial Cable (50 Ω)
11. Bulkhead Connector
12. RF Generation Equipment
13. RF Absorber Material

#### 12.6.1.2 ALSE Method (Bands 7 and 8)

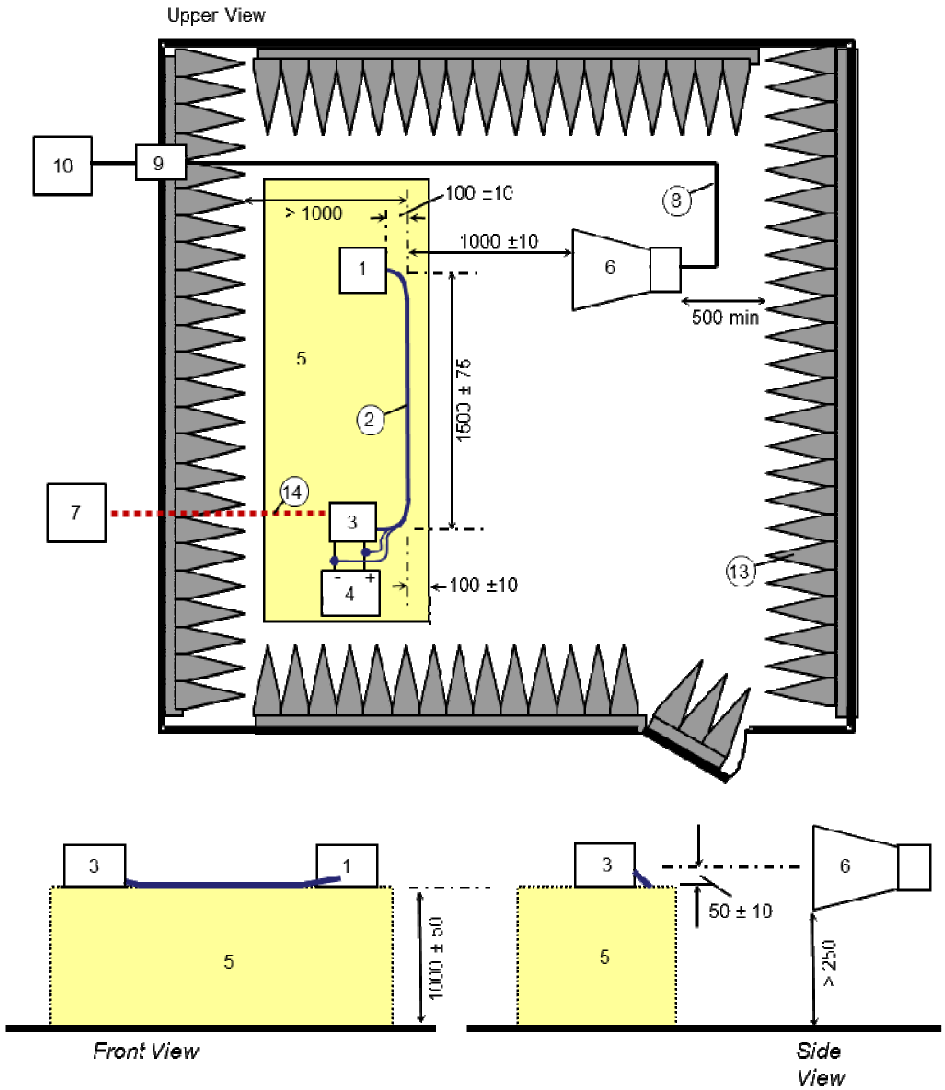
The test setup is illustrated in Figure 12-5.

- A ground plane shall not be used for this test.
- The DUT and its cable harness, along with the Load Simulator shall lie on a dielectric support 1000 mm (+/-50 mm) above the floor of the test chamber. The dielectric constant of the dielectric support shall be less than 1.4.
- An automotive battery shall be used to power the DUT and shall be place on the dielectric support with the DUT and Load Simulator. The power and returns from the DUT shall be connected directly to battery's positive and negative terminals. The Artificial Network shall not be used.
- The Artificial Network shall not be used.

#### 12.6.1.3 Reverberation Method

- The test setup shall conform to that specified in IEC 61000-4-21
- The reverberation chamber shall be sized large enough to test a DUT within the chamber's working volume.
- Ground plane shall not be used for this test.
- The DUT and its cable harness, along with the DUT and Load Simulator shall lie on a dielectric support within the middle of the test volume. The dielectric constant of the dielectric support shall be less than 1.4.
- An automotive battery shall be used to power the DUT and shall be place on the dielectric support with the DUT and Load Simulator. The power and returns from the DUT shall be connected directly to battery's positive and negative terminals. The Artificial Network shall not be used.
- The DUT shall be at least 250 mm from the chamber walls, tuner, transmit antenna, and receive antenna.
- The DUT and its cable harness, along with the DUT and Load Simulator shall lie on a dielectric support within the middle of the test volume. The dielectric constant of the dielectric support shall be less than 1.4.
- The mechanical tuner shall be as large as possible with respect to overall chamber size (at least three-quarters of the smallest chamber dimension) and working volume considerations. Each tuner should be shaped such that a non-repetitive field pattern is obtained over one revolution of the tuner.
- The electric field probes shall be capable of reading and reporting three orthogonal axes.
- The RF signal generator shall be capable of covering the frequency bands and modulations specified.
- The transmit antenna shall be linearly polarized and capable of satisfying the frequency coverage requirements. The transmit antenna shall not directly illuminate the test volume.
- The receive antenna shall be linearly polarized and capable of satisfying the frequency coverage requirements. The receive antenna shall not be directed into the test volume.
- Associated equipment shall be present to record the power levels necessary for the required field strength.

**Figure 12-5: RI 114 ALSE Test Setup ( Bands 7 and 8 )**




**Key:**

1. DUT
2. Test Harness
3. Load Simulator
4. Automotive Battery
5. Dielectric Support ($\varepsilon_r \leq 1.4$)
6. Transmit Antenna
7. Support Equipment
8. Double Shielded Coaxial Cable (e.g. RG 223)
9. Bulkhead Connector
10. RF Generation Equipment
11. RF absorber Material

### 12.6.2 Test Procedures

The DUT operating mode(s) exercised during testing shall conform to that delineated in the EMC test plan.

#### 12.6.2.1 ALSE Method

Testing shall be performed using the substitution method. Refer to ISO 11452-2 for field characterization procedures for Bands 5 and 6. Refer to Annex A for field characterization procedures for Bands 7 and 8.

For both procedures, field characterization shall be performed at the Level 2 field strengths listed in Table 12-5. Field characterization at lower field strengths with subsequent power scaling for higher field strengths is not permitted.

> *When performing testing in Bands 7 and 8, the forward power required to achieve the field strengths listed in Table 11-3 is greatly influenced by the transmit horn antenna selected. The antenna near field gain compression characteristics can significantly impact the actual power needed to achieve the required field strengths at 1 meter. Given this issue, selection of the antenna should not be based simply on the published antenna gain. Also, the high power levels needed to achieve the desired field strength have been shown to significantly impact the VSWR of some antennas. A list of recommended antennas may be found at http://www.fordemc.com.*

a) When performing testing in Bands 7 and 8 using pulse modulation, CW shall not be used for leveling prior to application of pulsed modulation.

b) Use the test frequencies listed in Tables 12-2 and 12-3. Use the modulation as specified in Table 12-5.

d) All modulation dwell time (i.e., time that RF is applied for per modulation type) shall be at least 2 sec.

e) The test shall be performed using both horizontal and vertical antenna polarization.

f) At test frequencies ≥ 1000 MHz, the DUT shall be tested in a minimum of three (3) orthogonal orientations unless otherwise stated in the EMC test plan.

#### 12.6.2.2 Reverberation Method

a) Before testing may commence, the test chamber shall be calibrated according to IEC 61000-4-21. with the exception that Table 12-6 be used to replace Table B1, Sampling Requirements, of IEC 61000-4-21 A.1 (Chamber Calibration and Loading Validation

b) Use test frequencies according to Table 12-3. Use the modulation specified in Table 12-5 except for bands 7 and 8. For bands 6 and 7, increase the pulse duration (PD) to 6 usec.

c) All modulation dwell time (i.e., time that RF is applied for per modulation type) shall be at least 2 s.

d) Electric field probes shall not be used during the test.

e) The transmit antenna shall be in the same location as used for calibration.

f) The DUT shall be exposed to each field level and frequency at each mode tuner position.

**Table 12-6: Independent Samples**

| **Frequency Range (MHz)** | **Number of Samples**<br>(i.e., independent tuner positions or intervals)<br>Recommended for Calibration and Test |
|---|---|
| 360 to 1000 | 12 |
| 1000 to 2000 | 6 |

## 12.7 Requirements 360 – 2700 MHz: RI 115

The device shall operate as specified in Table 12-1 when exposed to RF electromagnetic stress levels delineated in Table 12-7. RI 115 simulates near-field electromagnetic field exposure from OEM and customer installed cellular transmitters.

**Table 12-7: RI 115 Requirements**

| Band | Frequency Band (MHz) | Test Severity (Watts) (1) | | Modulation type |
|---|---|---|---|---|
| | | Level 1 | Level 2 | |
| 9 | 360-480 | 4.5 | 9.0 | PM PRR= 18 Hz, PD= 28 msec |
| 10 | 800 -1000 | 7.0 | 14.0 | PM PRR= 217 Hz, PD= 576 usec |
| 11 | 1600-1950 | 1.5 | 3.0 | PM PRR= 217 Hz, PD= 576 usec |
| 12 | 1950-2200 | 0.75 | 1.5 | PM PRR= 217 Hz, PD= 576 usec |
| 13 | 2400 -2500 | 0.1 | 0.2 | PM PR= 1600 Hz, PD= 313 usec |
| 14 | 2500-2700 | 0.25 | 0.5 | PM PRR= 217 Hz, PD= 576 usec |

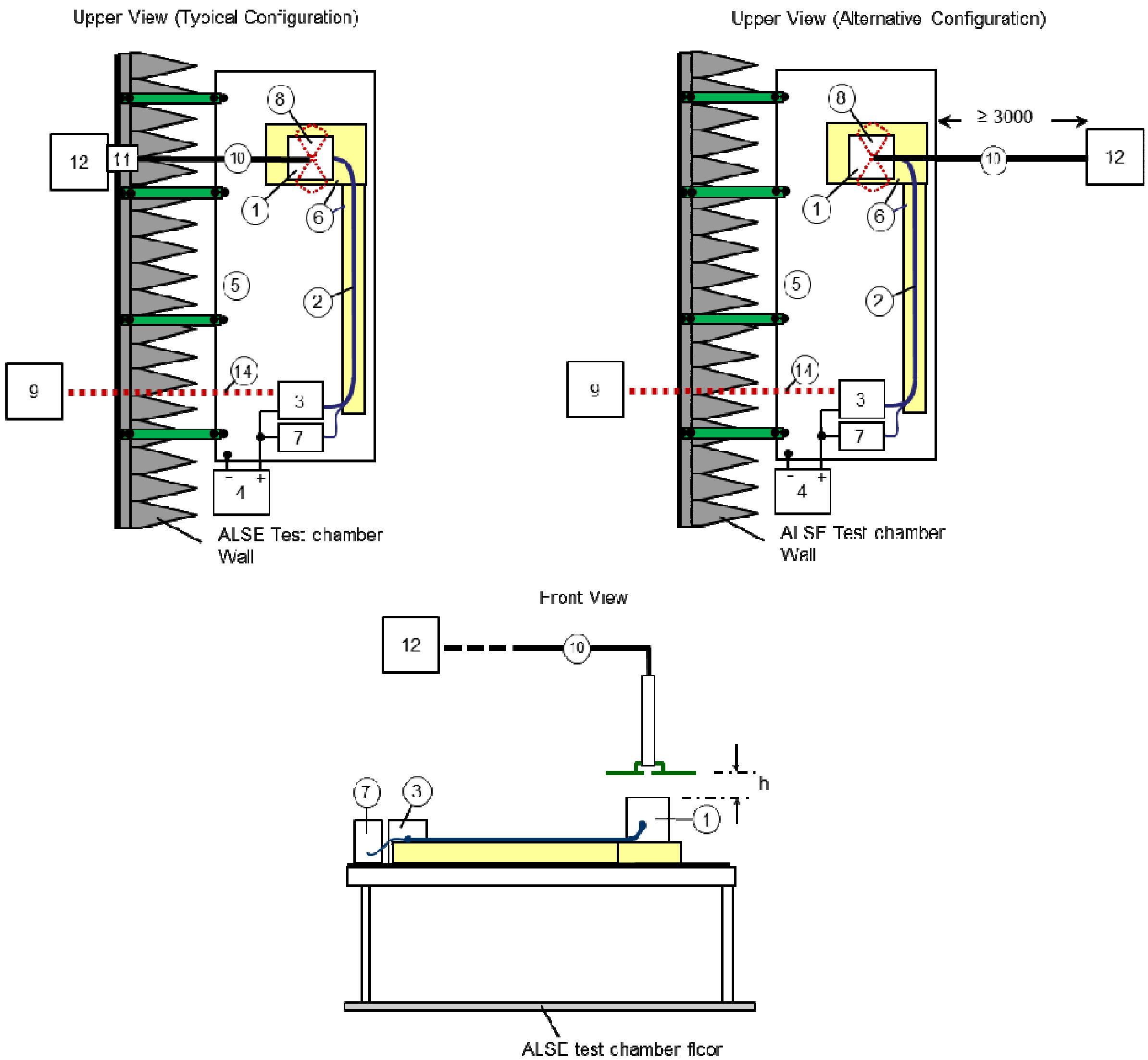
1. Test severity levels are based on NET power delivered to the input port of the antenna identified in the associated test verification.

### 12.7.1 Test Verification and Test Setup

Verification of component performance shall be performed in accordance with ISO 11452-9 except where delineated in this specification. This test procedure makes use of a small broadband antenna positioned above the DUT and it's wiring harness to simulate electromagnetic fields generated by hand portable transmitters operating in close proximity. The near-field characteristics are strongly influenced by the antenna type used and for this reason only Schwarzbeck antenna SBA9113 with elements 420NJ shall be used for this test. Substitutions are not permitted.

- The test setup is shown in Figure 12-6. In most typical configurations, the RF generation equipment is located outside of the test chamber. However, for RI115, the RF generation equipment may be located in the test chamber as long as it is ≥ 3 meters from the test bench. See Annex C for additional details regarding the test setup configuration and requirements for the RF generation equipment.
- The separation between the test antenna and the DUT surfaces and harnesses shall be either 5 mm or 50 mm depending on component category /usage as detailed in Table 12-8 below. DUT surfaces shall be partitioned into 100 mm or 30 mm square areas depending on the antenna separation distance selected. See section 12.7.2 for additional details. Antenna separation and position information shall be documented in the component level EMC test plan. Only one test antenna to DUT height shall be used for a given device.
- The test bench shall include a sufficiently large ground plane, such that the plane extends beyond the test setup by at least 100 mm on all sides.
- The distance between the test setup and all other conductive structures (such as the walls of the shielded enclosure) with the exception of the ground plane shall be ≥ 500 mm.
- The test antenna shall be mounted above the DUT such that the antenna elements are parallel to the ground plane. The barrel of the antenna shall be perpendicular to the ground plane. The DUT shall be positioned to ensure that the surface under test is facing toward the antenna
- References to wiring harness and Artificial Network are not applicable in case of modules with Component Category AW.

**Figure 12-6: RI 115 Test Setup**




**Key:**

1. DUT
2. Test Harness
3. Load Simulator
4. Power Supply
5. Ground Plane
6. Dielectric Support ($\varepsilon_r \leq 1.4$)
7. Artificial Network
8. Test antenna (Schwarzbeck antenna SBA9113 with elements 420NJ )
9. Support Equipment
10. Low loss coaxial cable assembly (See Annex C). Cable can be no closer than 1000 mm to antenna elements.
11. Bulkhead RF Coaxial Connector
12. RF Generation Equipment

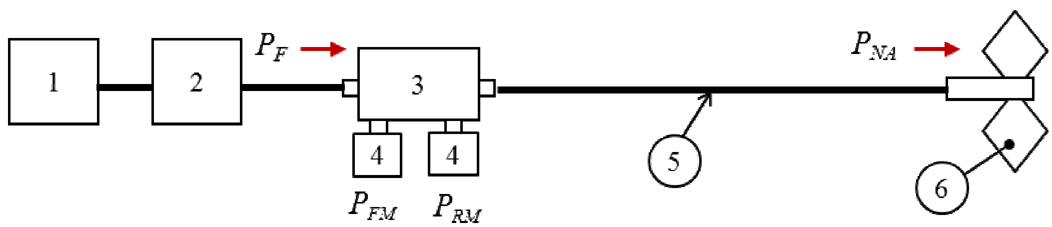
**Table 12-8: RI 115 Antenna Separation Distances and Positioning**

| DUT Surface or Harness description | Antenna Distance from DUT | Antenna Positioning Steps |
|---|---|---|
| DUTs including their connector(s) and wiring harness(s), any of which may be packaged near a cellular transmitter. Excludes engine compartment packaging (see Table 7-2) | 50 mm | 100 mm |
| Selected DUTs (e.g. AW) which may come in direct contact with the cellular transmitter. FNA EMC determines applicability. | 5 mm | 30 mm |

### 12.7.1.1 RF Generation Equipment Requirements

Figure 12-7 illustrates the basic setup for the RF generation equipment. The net power level ($P_{NA}$) per Table 12-7 is derived from the forward power ($P_{FM}$) measured at the directional coupler, which is remotely connected to the SBA antenna via low loss coaxial cable. Requirements on directional coupler, cable and power sensors are listed in Table 12-9. The procedures delineated in Annex C shall be used determine the required forward power to achieve the net power levels listed in Table 12-7. Although not required, it is highly recommended to use a single directional coupler to cover the entire frequency band.

**Figure 12-7: RF Generation Equipment Setup**




**Key:**

1. RF/uW Signal Generator
2. RF/uW Amplifier
3. Dual Directional Coupler (e.g. Werlatone C7711)
4. Peak Wideband Power Sensor (e.g. R&S NRP-Z81)
5. Low Loss Coaxial Cable
6. SBA Antenna

**Table 12-9: Test Equipment Performance Requirements**

| | |
|---|---|
| Dual Directional Coupler: | |
| Coupling Factor: | > 20 dB (40 dB preferred)[1] |
| Coupling Port VSWR | < 1.5 |
| Mainline Transmission Loss: | < 0.5 dB |
| Mainline port VSWR: | < 1.25 |
| Directivity: | > 18 dB |
| Interconnecting Cable (includes adaptors, switches etc) | |
| Characteristic Impedance: | 50 Ω |
| Transmission Loss: | < 4 dB |
| VSWR: | < 1.1 |
| Peak Wideband Power Sensor (1) | |
| VSWR: | < 1.2 |
| Accuracy: | ≤ 0.13 dB |
| *Verification of these individual requirements is part of the characterization process per Annex C. Reliance on manufactures data is not acceptable.* | |

1. Selection of coupling factor must be compatible with the sensitivity of the measurement equipment used to measure forward and reflected power.
2. Although not recommended, A spectrum analyzer may be used in place of peak power sensors with approval from FMC EMC department

### 12.7.2. Test Procedure

Prior to testing, characterization of test setup shall be performed in accordance with the procedures delineated in Annex C. The characterization will determine and document the forward power required to generate the specified net power per Table 12-7 delivered to the antenna at the test frequencies listed in Table 12.4. During actual testing, the same forward power values shall be used regardless of any DUT influence on the reflected power. See Annex B for leveling and threshold requirements.

The methodology for selection of surfaces and harnesses to be tested, in addition to antenna to DUT test distance and antenna positioning steps is delineated in sections 12.7.2.1 and 12.7.2.2 below. This information shall be documented in the EMC test plan.

#### 12.7.2.1. Antenna Positioning for Coupling to DUT

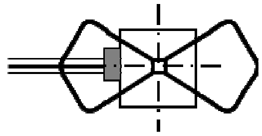
Per Table 12-8, the usable test area of the broadband antenna is 100x100 mm when testing at a DUT-to-antenna separation of 50 mm. However, the footprint reduces to 30x30 mm when testing at 5 mm separation. It is therefore necessary to move the antenna in steps of 100 mm and 30 mm when testing at 50mm and 5mm respectively.

All surfaces of the DUT which are to be tested shall be partitioned to square cells of either 100x100, or 30x30 mm. The antenna shall be placed at a distance of 50 or 5 mm (specified in the test plan) and the center of each cell shall be exposed to the center and the elements of the antenna in two orthogonal orientations (four exposures in total). It is necessary to expose each cell to the center and the elements of the antenna as E and H fields are in different places and move with test frequency.

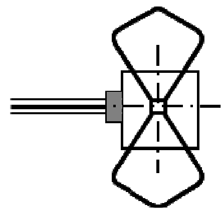
The antenna shall be placed above the center of each cell, and the DUT shall be exposed to specified stress levels listed in Table 12-7 using the test sequence detailed below. For each cell, testing requires four separate antenna positions, as illustrated for a single cell in the steps below.

> *Note that when testing DUTs with multiple cells, positioning of the antenna so as to expose adjacent cells is possible thus reduction in test time is possible.*

a) Place the antenna in parallel with the DUT harness and aligned with the center of the first cell and expose DUT to stress levels specified in Table 12-7 at the test frequencies listed in Table 12-4.



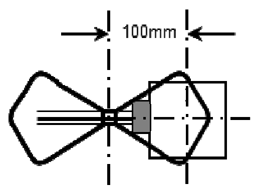
b) Repeat step a) with antenna rotated 90 degrees



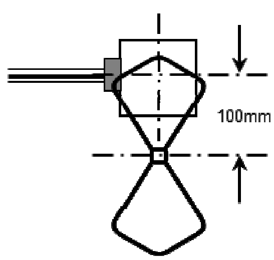
c) Align antenna with the center of the next cell and repeat steps (a) and (b) until all cells have been exposed to 2 orthogonal orientation of the antenna.

Steps (d), (e) and (f) are NOT required when testing at 5mm distance.

d) Move the antenna back to the first cell. Align antenna element in the center of the test cell (edges of the element aligned with the center of the cell) and expose DUT to the stress levels specified in Table 11-4.




e) Repeat step d) with antenna rotated 90 degrees



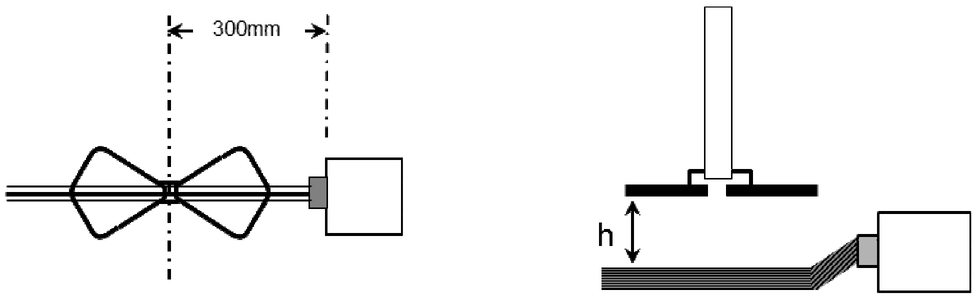

f) Repeat steps (d) and (e) until all cells have been exposed. When testing DUTs with multiple cells, centers of some cells will be exposed to the elements of the antenna while performing steps (a) to (c) to the adjacent cell. In such cases, it is not required to carry out steps (d) and (e) that would result in a duplicate test. If there is any doubt over effective exposure of cells to the elements of the antenna, steps (d) and (e) shall be performed.

g) Repeat steps a) through f) for each DUT surface defined in the EMC test plan. Testing requires rotation of the DUT such that the surface to be tested is parallel to the ground plane. Low permittivity ($\varepsilon_r \leq 1.4$) material shall be used to support DUT so that the surface under test is facing up toward the antenna.

### 12.7.2.2. Antenna Positioning for Coupling to Harness Connection

a) Position the antenna above the DUT harness at 300 mm from the DUT connector as illustrated in Figure 12-8. The distance between the antenna and harness shall be either 50 or 5mm as delineated in the EMC test plan.
b) At each of the four positions described in section 12.7.2.1, steps a), b), d) and e), expose DUT harness to the stress levels specified in Table 12-7.
c) Repeat steps a) and b) for each DUT harness as delineated in the EMC test plan

**Figure 12-8: RI 115 Antenna Positioning for Testing the Harness**




**a) Top View** **b) Side View**

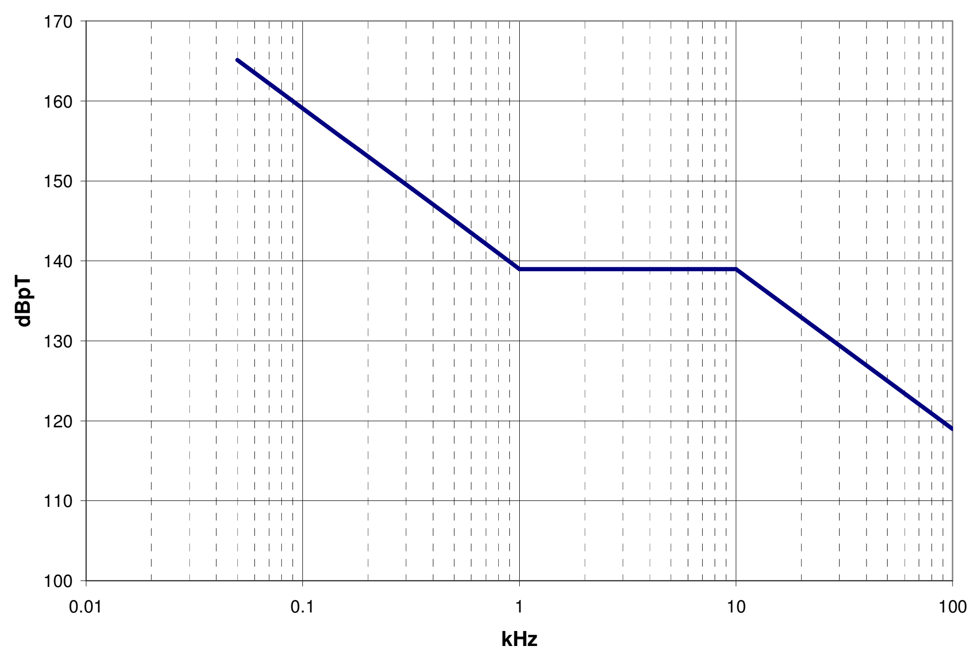
## 13.0 Magnetic Field Immunity: RI 140

Magnetic Field Immunity is based on anticipated “off-vehicle” electromagnetic sources (e.g. AC power lines) in addition to “on-vehicle” sources (e.g. charging system, PWM sources). Magnetic field immunity requirements cover the frequency range from 50 Hz to 100 kHz Requirements.

### 13.1 Requirements

The function of the component including any attached magnetic sensors (if applicable) shall operate without deviation (Status I) when exposed to the magnetic field levels delineated in Figure 13-1.

**Figure 13-1: RI 140 Magnetic Field Immunity Requirements**




| Frequency (kHz) | Level (dBpT rms) |
|---|---|
| 0.05 - 1 | $165 - 20\log\left(f/0.05\right)$ * |
| 1 – 10 | 139 |
| 10 – 100 | $139 - 20\log\left(f/10\right)$ * |

* $f$ = frequency in kHz

## 13.2 Test Verification and Test Setup

Verification of component performance shall be verified using the test method delineated in ISO 11452-8 except where noted in this specification. The test setup shall be configured to facilitate direct exposure of the DUT to the fields listed in Figure 13-1 in addition to magnetic field exposure to any magnetic sensors that may be connected to the DUT. This may be accomplished using either of the following devices:

- 120 mm diameter magnetic radiating loop with self resonance greater than 100 kHz (e.g. ETS Lindgren Model 7603).
- Helmholtz coil with self resonance greater than 100 kHz (e.g. ETS Lindgren Model 6402M).

The respective test setup configurations are illustrated in Figure 13-2 and 13-3. Testing shall be performed at the frequencies listed in Table 13-1. For either test method, the loop current shall only be monitored by a current probe with sufficient bandwidth (use of shunt resistors are not permitted).

**Table 13-1: RI 140 Test Frequency Requirements**

| Test Frequency Range (kHz) | Frequency Step (kHz) |
|---|---|
| .05 -1 | .05 |
| > 1 – 10 | 0.5 |
| > 10 - 100 | 5 |

The DUT shall be placed on a wooden table or insulated table for either test method. The Load Simulator and other support equipment shall be mounted to a ground plane; however no portion of the Load Simulator or ground plane shall be closer than 200 mm to the radiating loop or Helmholtz coils.

The power supply negative terminal shall be connected to the ground plane bench. The power supply shall be placed on the floor below or adjacent to the test bench.

## 13.3 Test Procedures

The DUT operating mode(s) exercised during testing shall conform to that delineated in the EMC test plan.

### 13.3.1 Radiating Loop Method

*a)* Prior to performing testing of the DUT, calibrate the radiation loop using procedures delineated in *MIL-STD-461E, RS101.*

b) Partition each face of the DUT into 100 x 100 mm square areas and position the radiating loop face to the center of each of these areas. If the DUT face is less than 100 x 100 mm, place the radiating loop in the center of the DUT face. Separation between the face of the radiating loop and DUT surface shall be 50 mm. Orient the plane of the loop sensor parallel to the DUT faces and parallel to the axis of any connector.

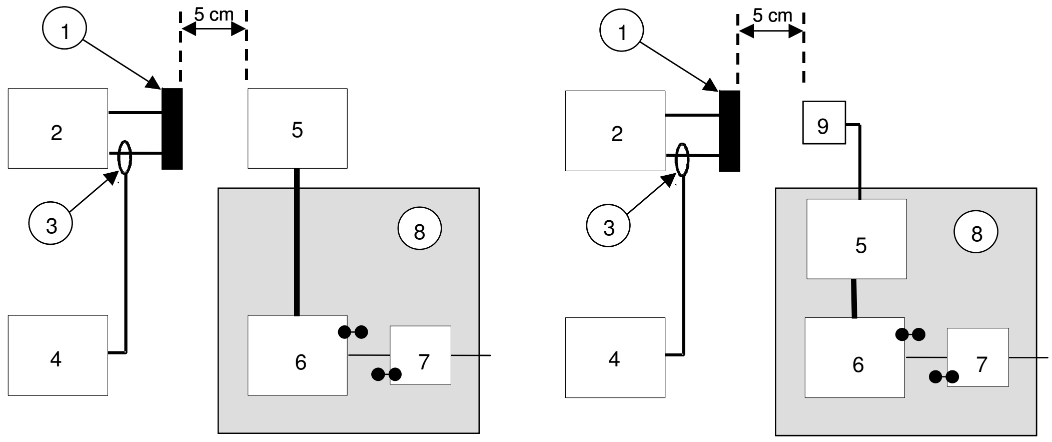
c) At each position, supply the loop with sufficient current to produce the corresponding magnetic field levels delineated in Figure 13-1 at each test frequency step listed in Table 13-1.

d) Dwell time shall be at least 2 seconds. A longer dwell time may be necessary if DUT function response times are expected to be longer. This information shall be documented in the EMC test plan.

e) If deviations are observed, the field shall be reduced until the DUT functions normally. Then the field shall be increased until the deviation occurs. This level shall be reported as deviation threshold.

f) If the DUT has magnetic sensors attached to it, separate tests shall be performed exposing only the sensor while verifying correct operation of the DUT (see Figure 13-2).

**Figure 13-2: RI 140 Magnetic Immunity Test Setup: Radiating Loop**




**Configuration for Testing DUT only**

**Configuration for Testing DUT with attached Magnetic Sensors**

**Key:**

1. Radiating Loop
2. Signal Source
3. Current Probe
4. Measurement Receiver
5. DUT
6. Load Simulator
7. Artificial Network
8. Ground Plane
9. Magnetic Sensor

### 13.3.2 Helmholtz Coil Method

a) Prior to performing testing of the DUT, characterize the Helmholtz Coil using procedures delineated in *MIL-STD-461E, RS101*. Select coil spacing based on the physical dimensions of the DUT.

- For a DUT with dimensions less than one coil radius, the coils shall be separated by one coil radius. Separation between each surface of the DUT and either coil shall be at least 50 mm.
- For a DUT with dimensions greater than one coil radius, the coils shall be separated such that the plane of the DUT face is at least 50 mm from the plane of either coil and the separation between the two coils does not exceed 1.5 radii.

b) Supply the Helmholtz Coil with sufficient current to produce the corresponding magnetic field levels delineated in Figure 13-1 at each test frequency listed in Table 13-1.

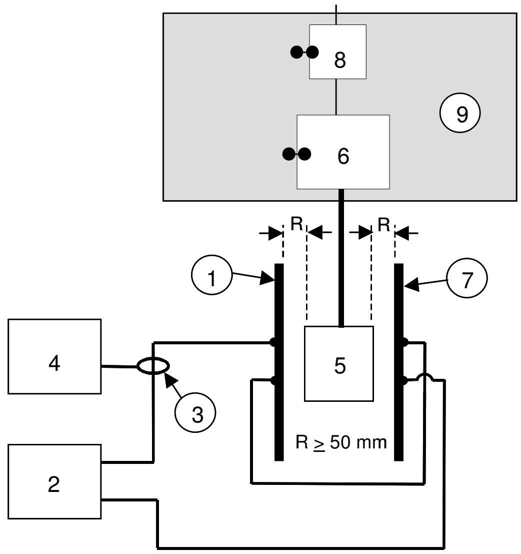
c) Dwell time shall be at least 2 seconds. A longer dwell time may be necessary if DUT function response times are expected to be longer. This information shall be documented in the EMC test plan.

d) Reposition the DUT or Helmholtz coils successively such that the two coils are parallel to each face of the DUT and parallel to the axis of any connector.

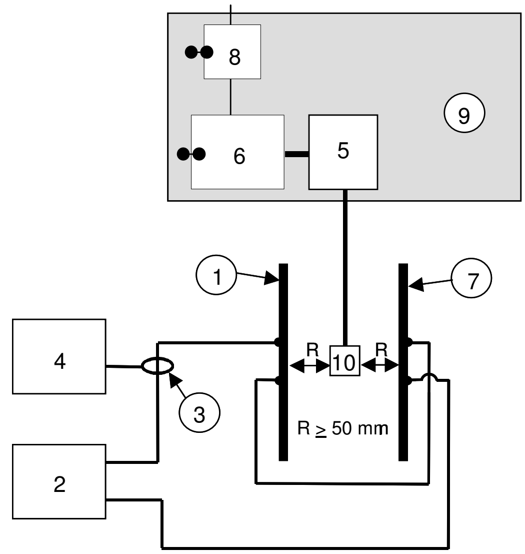
e) If deviations are observed, the field shall be reduced until the DUT functions normally. Then the field shall be increased until the deviation occurs. This level shall be reported as deviation threshold.

f) If the DUT has magnetic sensors attached to it, separate tests shall be performed exposing only the sensor while verifying correct operation of the DUT (see Figure 13-3).

**Figure 13-3: RI 140 Magnetic Immunity Test Setups for Helmholtz Coil**




**Configuration for Testing DUT only**




**Configuration for Testing DUT with attached Magnetic Sensors**

Key:

1. Radiating Loop A
2. Signal Source
3. Current Probe
4. Measurement Receiver
5. DUT
6. Load Simulator
7. Radiating Loop B
8. Artificial Network
9. Ground Plane
10. Magnetic Sensor

## 14.0 Coupled Immunity: RI 130

These requirements are related to component immunity from wire-to-wire coupling of unintended transient disturbances. These disturbances originate from switching of inductive loads including solenoids and motors.

### 14.1 Requirements

The function of the component shall operate without deviation (Status I) when exposed to coupled transient electromagnetic disturbances created from switch contact arching and bounce. The requirements are delineated in Table 14-1. The source transient disturbance characteristics are identical to Modes 2 and 3; Pulses A2-1 and A2-2. See Annex D regarding details of these transient waveforms and the mode of application.

**Table 14-1: RI 130 Coupled Immunity Requirements**

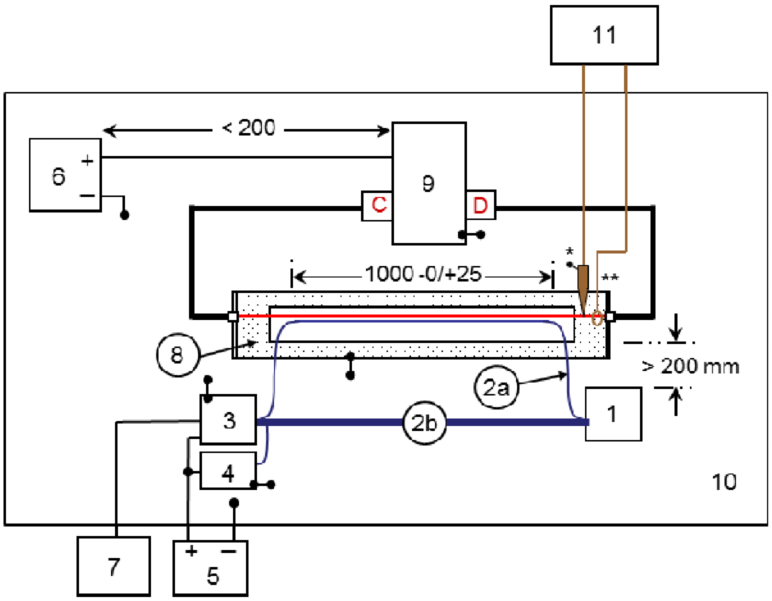
| Mode | Pulse |
|---|---|
| 2 | A2-1 |
| | A2-2 |
| 3 | A2-1 |
| | A2-2 |

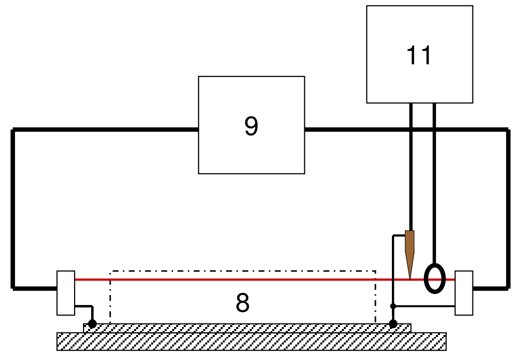
### 14.2 Test Verification and Test Setup

Verification shall be performed using the basic test setup shown in Figure 14-1. The setup involves removal of individual wires from the DUT wire harness and placed in the test fixture for testing. Information regarding testing of twisted and/or shielded wires may be found in Annex G along with a basic description of the test fixture. Details regarding fabrication of the test fixture are found at http://www.fordemc.com. Information regarding the transient pulse characteristics and the transient generator may be found in Annex D and F respectively.

- The power supply negative terminal shall be connected to the ground plane bench. The power supply may be placed on the floor below or adjacent to the test bench.
- The DUT power shall be connected to the power supply via Artificial Network (AN). The AN shall conform to CISPR 25. The AN's measurement ports shall be terminated with 50 ohms.
- The Transient Generator shall be powered from a vehicle battery or power supply (See Section 5.5.4 for requirements). The metal case of the transient generator shall be connected to the ground plane. See Annex E regarding details of the transient generator.
- The DUT and all parts of the test setup shall be a minimum of 100 mm from the edge of the ground plane.
- A digital sampling oscilloscope shall be used for test voltage/current verification. The oscilloscope shall have the following capabilities:
  - A minimum capable sampling rate of 1 Giga-samples per second (single shot capability).
  - A minimum memory depth of 8 mega-samples for a single channel.
- Voltage and current probes are required to facilitate verification of the transient disturbance. Requirements for these probes are found in Figure 14-1.
- If the outer case of the DUT is metal and can be grounded when installed in the vehicle, the DUT shall be electrically bonded directly to the ground plane (*similar as implemented in the vehicle*) during testing. If the DUT case is not grounded in the vehicle, the DUT shall be placed on a dielectric support 50 mm above the ground plane.
- Untested wires shall be bundled together and lie directly on the ground plane. The distance between the untested wires and the test fixture shall be greater than 200 mm.

**Figure 14-1: RI 130 Default Test Setup**




Detail

**Key**

| | | | |
|---|---|---|---|
| 1 | DUT | 7 | DUT Monitor/Support Equipment |
| 2a | DUT Circuit Wire to be Tested | 8 | Coupling Test Fixture |
| 2b | DUT Wire Harness | 9 | Transient Generator (see Annex E for details). Generator connected to Coupling test fixture via coaxial cable. Case of generator connected to the ground plane. |
| 3 | Load Simulator | 10 | Ground Plane |
| 4 | Artificial Network | 11 | Digital Oscilloscope (≥1 GS/sec, ≥ 8 Mega sample) |
| 5 | Power supply | * | 1:100 high impedance probe (C < 4 pf) per ISO 7637-2. Example: Agilent 10076A) |
| 6 | Automotive Battery | ** | Current Probe (> 10 MHz, 30 A) Example: Agilent N2783A |

### 14.3 Test Procedures

Testing shall be repeated for all DUT operating modes listed in the EMC test plan.

a) Configure the transient generator for Mode 3, Pulse A2-1 (see Annex E). Close SW0 to activate the transient generator. Using the oscilloscope, capture at least one complete transient sequence (see Figure D-12).

b) Verify magnitude of the negative transient voltage disturbance measured at the test point (see Figure 14-1) is greater than 300 volts. When completed, open SW0 to deactivate the transient generator.

c) Repeat steps a) and b) with transient generator configured for Mode 3, Pulse A2-2. Verify that the peak-to-peak transient current disturbance exceeds 20 amperes.

d) Open SW0 to deactivate the transient generator. Configure the transient generator for Mode 2, Pulse A2-1.

e) Activate the DUT and verify that it is functioning correctly.

f) Place an individual DUT circuit wire in Slot A of the test fixture. See Annex G for specific requirements with respect to circuit wire types and their placement in the test fixture. DUT wire location shall be documented in the EMC test plan and report.

***DUT circuit wires with DC currents exceeding 20 amperes are excluded from this testing.***

g) Close SW0 to activate transient generator.

h) Expose the circuit wire(s) for 60sec. *A longer dwell time may be necessary if DUT function response times are expected to be longer. This information shall be documented in the EMC test plan./* Verify that DUT performance is not affected. (i.e. Status I)

i) Repeat step h) with the transient generator configured in the following modes:

- Mode 2, Pulse A2-2
- Mode 3, Pulse A2-1
- Mode 3, Pulse A2-2

j) Repeat steps d) through i) for remaining DUT circuit wires.

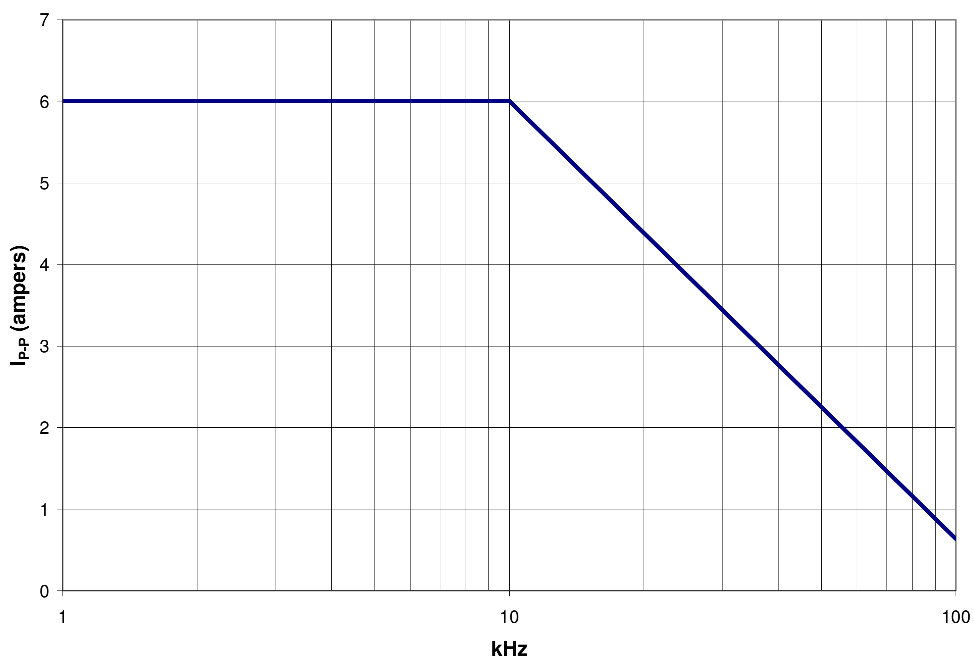
## 15.0 Coupled Immunity: RI 150

These requirements are related to component immunity from wire-to-wire coupling of unintended continuous disturbances. These disturbances originate from high current PWM sources and the vehicle's charging and ignition system. .

### 15.1 Requirements

The function of the component shall operate without deviation (Status I) when exposed to sinusoidal electromagnetic disturbances delineated in Figure 15-1.

**Figure 15-1: RI 150 Coupled Immunity Requirements**



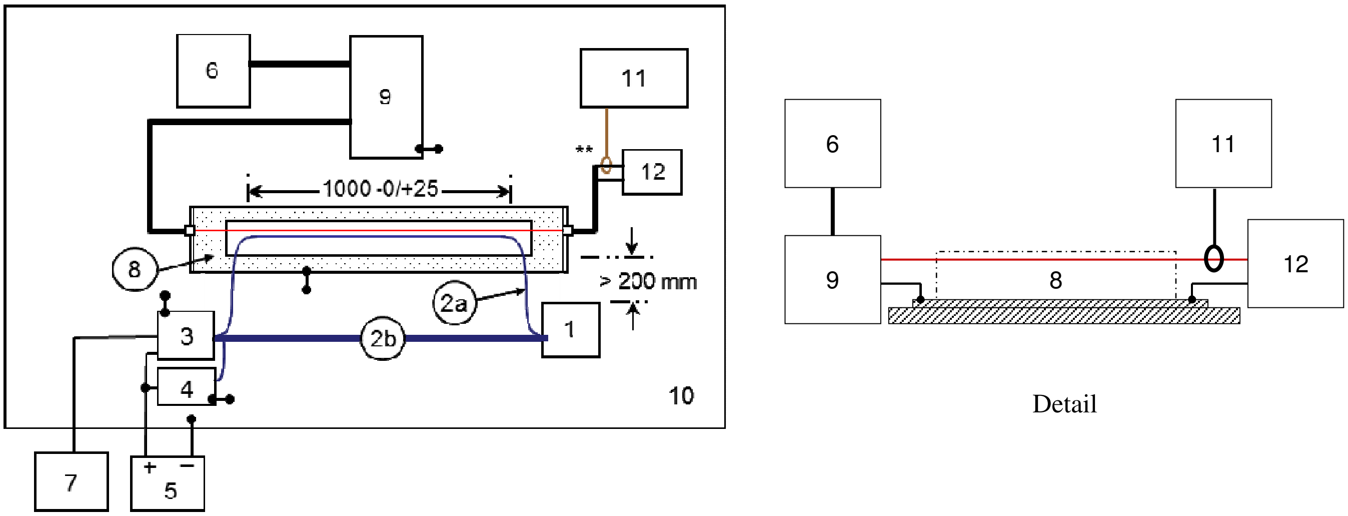

| Frequency (kHz) | Stress Level ( $I_{P-P}$ ) |
|---|---|
| 1 – 10 | 6 |
| 10 – 100 | $6 - 5.4\log\left(\frac{f}{10}\right)$ * |

* $f$ = frequency in kHz

### 15.2 Test Verification and Test Setup

Verification shall be performed using the test Setup shown in Figures 15-2. Except where noted in Figure 15-2, the setup of the DUT, Load Simulator and test harness is identical to that used for RI 130.

**Figure 15-2: RI 150 Test Setup**




**Key**

| | | | |
|---|---|---|---|
| 1 | DUT | 7 | DUT Monitor/Support Equipment |
| 2a | DUT Circuit Wire to be Tested | 8 | Coupling Test Fixture |
| 2b | DUT Wire Harness | 9 | Amplifier ( 1kHz – 100 kHz ) |
| 3 | Load Simulator | 10 | Ground Plane |
| 4 | Artificial Network | 11 | Digital Oscilloscope (≥1 GS/sec, ≥ 8 Mega sample) |
| 5 | Power supply | 12 | Amplifier Load Resistance (e.g. 4 ohms) |
| 6 | Signal Generator | ** | Current Probe (> 10 MHz, 30 A) Example: Agilent N2783A |

## 15.3 Test Procedures

Testing shall be repeated for all DUT operating modes listed in the EMC test plan.

a) Activate the DUT and verify that it is functioning correctly.

b) Place an individual DUT circuit wire or wire pairs (i.e. twisted wire pair) in the test fixture *(circuit placement requirements are identical to RI130).*

***Circuit wires with currents exceeding 20 amperes are excluded from this testing.***

b) At each test frequency increase the peak to peak current to the corresponding stress level listed in Figure 15-1. Use the frequency steps listed in Table 15-1.

- Dwell time shall be 10 seconds. A longer dwell time may be necessary if DUT function response times are expected to be longer. This information shall be documented in the EMC test plan.

c) Monitor DUT functions before, during, and after application of the stress levels in Figure 15-1 and verify that no performance deviations occur (i.e. Status I).

**Table 15-1: RI 150 Test Frequency Requirements**

| Test Frequency Range (kHz) | Frequency Step (kHz) |
|---|---|
| > 1 – 10 | 0.5 |
| > 10 – 100 | 5 |

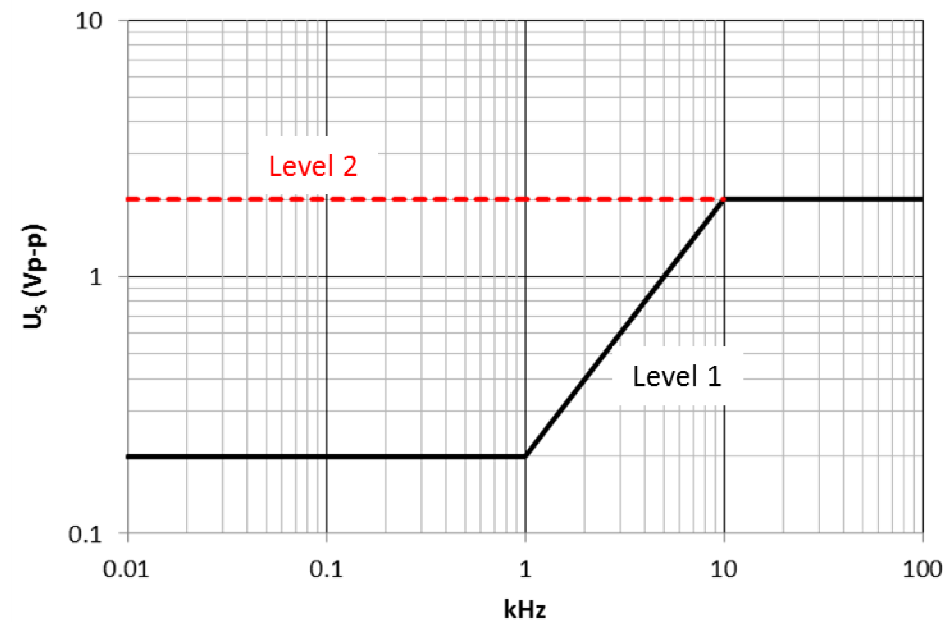
## 16.0 Immunity from Continuous Power Line Disturbances: CI 210

The function of the component/subsystem shall be immune from continuous disturbances that occur on the vehicle's power distribution system.

### 16.1 Requirements

The function of the component/subsystem shall operate without deviation (Status I) when exposed to sinusoidal electromagnetic disturbances shown in Figure 16-1.

**Figure 16-1: CI 210 Requirements**



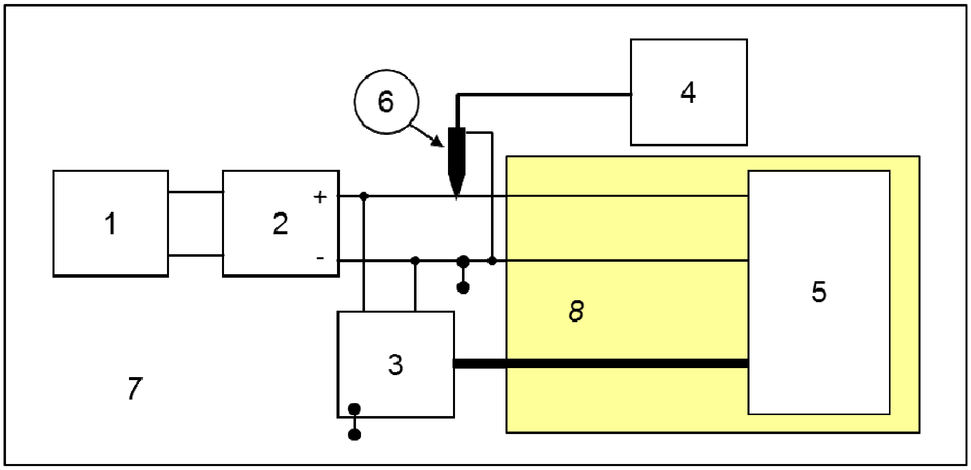

| Requirement Level | Frequency Range (kHz) | $U_S$ ( Vp-p ) | Functional Performance Status | | |
|---|---|---|---|---|---|
| | | | Class A | Class B | Class C |
| 1 | .01 - 1 | 0.2 | I | I | I |
| | 1 - 10 | $0.2 \cdot f$ | | | |
| | 10 - 100 | 2.0 | | | |
| 2 | .01 - 10 | 2.0 | III | II | II |

$f$ = frequency in kHz

## 16.2 Test Verification and Test setup

Testing shall be performed using the test setup shown in Figure 16-2. The test harness connecting the DUT to the Load Simulator and modulated DC supply shall be ≤ 2000 mm in length. All DUT power/power return circuits shall be connected together at the modulated power supply.

**Figure 16-2: CI 210 Test Setup**




**Key**

1. Signal Source
2. Modulated Power Supply *( DC coupled Audio Amplifier with output impedance < 100 milliohms may be used)*
3. Load Simulator
4. Oscilloscope
5. DUT
6. Passive High Impedance Probe (>1Mohm, C< 10 pf )
7. Ground Plane
8. Dielectric Support ($\varepsilon_r \leq 1.4$) 50 mm thick

## 16.3 Test Procedures

a) Without the DUT connected, adjust the DC voltage offset "$U_P$" of the modulated power supply to DUT's system voltage (13.5, 27 volts) per Figure 16-3. "$U_S$" is initially set to zero volts.

b) At each test frequency adjust and record the signal generator output required to achieve the specified modulation voltage level "$U_S$" with the DUT disconnected (open circuit). Use the frequency steps listed in Table 16-1.

c) Without the modulation signal present (i.e. $U_S$ = 0 volts), connect the DUT and verify it is functioning correctly.

d) At each test frequency, apply the signal generator levels recorded in step b) to the DUT and the Load Simulator such that all power and control circuits are exposed to the disturbance. The dwell time shall be at least 2 seconds. A longer dwell time may be necessary if DUT function response times are expected to be longer. This information shall be documented in the EMC test plan and test report.

e) Monitor and document any anomalies observed in DUT functionality

f) Repeat testing for all DUT operating modes listed in the EMC test plan.

**Figure 16-3: CI 210 AC Stress Level ($U_S$) Superimposed on DUT Supply Voltage ($U_P$)**

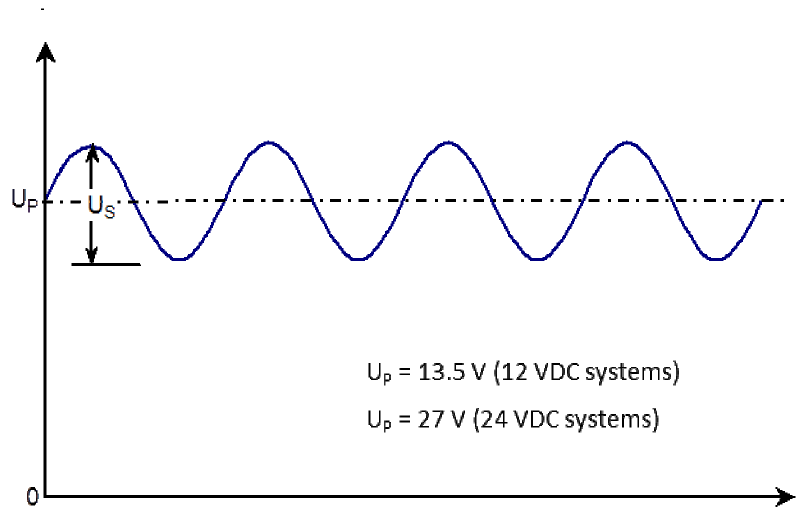



**Table 16-1: CI 210 Test Frequency Requirements**

| Test Frequency Range (kHz) | Frequency Step (kHz) |
|---|---|
| 0.01-0.05 | 0.01 |
| 0.05 - 1 | 0.05 |
| > 1 - 10 | 0.5 |
| > 10 - 100 | 5 |

## 17.0 Immunity from Transient Disturbances: CI 220

These requirements are related to immunity from conducted transients on 12 VDC power supply circuits in addition to control circuits connected directly to the vehicle's 12 VDC battery or indirectly by a switch or load (e.g. pull-up resistor). These requirements are limited to 12 VDC applications.

### 17.1 Requirements

The function of the component/subsystem shall meet the performance requirements delineated in Table 17-1. In addition to these requirements, the function of the component/subsystem shall not be affected (Status I) by transient voltages generated by result of its own operation, including switching of inductive loads either internal or external to the device (i.e. Category AX).

**Table 17-1: CI 220 Transient Immunity Requirements**

<table>
<tr><th rowspan="2">Transient Pulse [1]</th><th rowspan="2">Application</th><th colspan="2">Stress Level (Volts)</th><th rowspan="2">Transient Mode [1]</th><th rowspan="2">Minimum # of pulses or Test Duration</th><th rowspan="2">Functional Performance Status</th></tr>
<tr><th>$U_A$</th><th>$U_S$</th></tr>
<tr><td>ISO Pulse 1</td><td>Unswitched Power Supply Circuits</td><td>13.5</td><td>-100 [4]</td><td>n/a</td><td>5 [6, 7]</td><td>IV</td></tr>
<tr><td>ISO Pulse 1[5]</td><td>Switched Power Supply Circuits or Control Circuits ≥ 5 amperes</td><td>13.5</td><td>-100 [4]</td><td>n/a</td><td>24 pulses</td><td>II</td></tr>
<tr><td rowspan="2">Pulse A1 [2,5]</td><td>Switched Power Supply Circuits with Maximum Current < 5 amperes</td><td colspan="2" rowspan="5">See Annex D</td><td>Mode 1</td><td>120 sec</td><td>II</td></tr>
<tr><td>Control Circuits</td><td>Mode 2</td><td>20 sec</td><td>II</td></tr>
<tr><td>Pulse A2-1 [2,5]<br>Pulse A2-2 [2,5]</td><td>Switched Power Supply Circuits with Maximum Current < 5 amperes</td><td>Mode 1</td><td>120 sec</td><td>II</td></tr>
<tr><td>Pulse A2-1 [2]<br>Pulse A2-2[2]</td><td>Control Circuits</td><td>Mode 2<br>Mode 3</td><td>20 sec</td><td>II</td></tr>
<tr><td>Pulse C-1 [2]<br>Pulse C-2 [2]</td><td>All Power Supply Circuits (< 15A) [3]<br>Control circuits.</td><td>Mode 2<br>Mode 3</td><td>20 sec</td><td>I</td></tr>
</table>

(1) See Annex D for transient pulse characteristics of Pulses A1, A2 and C in addition to mode description. See ISO 7637-2 for Pulse 1 characteristics.
(2) See Annex E for test generator requirements to produce transient pulses A1, A2, and C.
(3) Pulse application occurs while power is supplied to the circuit
(4) $U_S$ represents open circuit condition. See Annex D for pulse characteristics
(5) *Pulse application may be dependent on DUT mode of operation (i.e. different DUT current draw). This shall be documented in the EMC test plan*
(6) *Delay between consecutive pulses ($t_1$) is ≥ 30 sec. See Figure D-6, Annex D for details*
(7) *See Annex H for explanation of Pulse application*

## 17.2 Test Verification and Test Setup

Verification of component performance shall be in accordance with ISO 7637-2 except where noted in this specification.

- The DUT and test harness shall be placed on a dielectric support 50 mm above the ground plane.
- Test pulses A1, A2-1, A2-2, C-1 and C-2 shall be generated using the transient generator described in Annex E. Wiring connecting the power supply to the transient generator shall be less than 200 mm to assure the transient characteristics shown in Annex D.
- The DUT and any electronic hardware in the Load Simulator and transient generator shall all be powered from the same power supply. The supply voltage shall set to 13.5 volts. See section 5.5.4 for additional requirements for the power supply.
- Artificial Networks shall not be used as part of the test setup.
- The test harness connecting the DUT to the Load Simulator and transient pulse generator shall be ≤ 2000 mm in length. Individual circuits under test shall remain bundled with the cable harness over the entire length up to the point where they must be separated out for connection to the test generator. *The figures below only provide schematic representation of the connections.*
- If the DUT has multiple power supply circuits (e.g. battery direct, ignition/run, relay) and/or control circuits, these circuits shall be configured to facilitate individual application of test pulses.
- A device powered from an external, unregulated supply located in another module shall be tested as a system with the sourcing module being subjected to the transient disturbance. Details of this setup shall be documented in the EMC test plan.
- Figure 17-1 illustrates the generic test setup for testing of a single DUT power supply circuit with a remote ground connection. In this example, the Load simulator power is connected directly to the power supply positive terminal.
- Figure 17-2 illustrates the test setup for devices with two supply circuits. In this configuration, the untested power supply circuit ($U_1$) and Load Simulator are connected directly to the power supply positive terminal. If the device has additional power supply circuits operating at the same voltage, those circuits should also be connected directly to the power supply positive terminal.
- Figure 17-3 illustrates the setup used for testing of control circuits. These circuits may be directly or indirectly connected to switched battery circuits (e.g switch or pull-up resistor). Further detail of this configuration is illustrated in Figure 17-4. The pull-up resistor or switch is located in the Load Simulator.

**Figure 17-1: CI 220 Test Setup for Devices with a Single Power Supply Circuit**

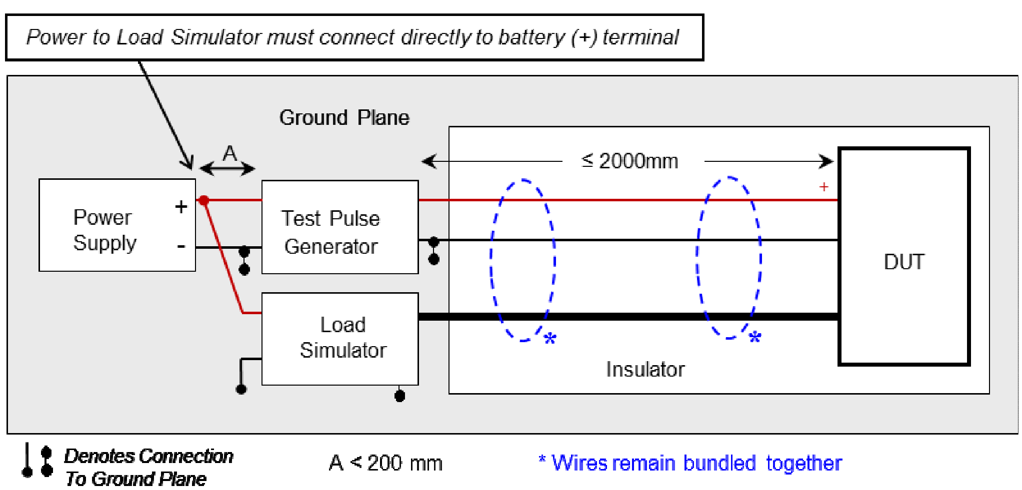


**Figure 17-2: CI 220 Test Setup for Devices with Two Power Supply Connections**

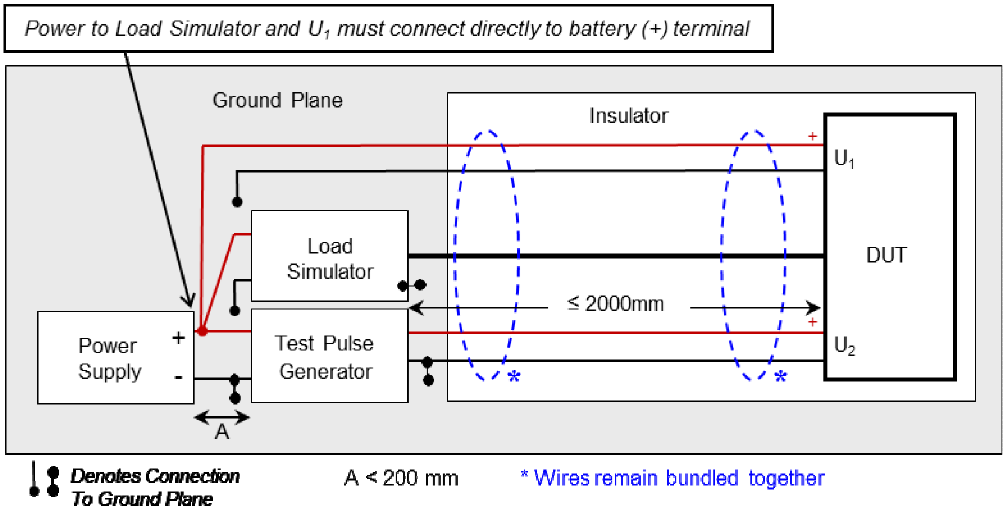



**Figure 17-3: CI 220 Test Setup for Devices with Input Circuits**

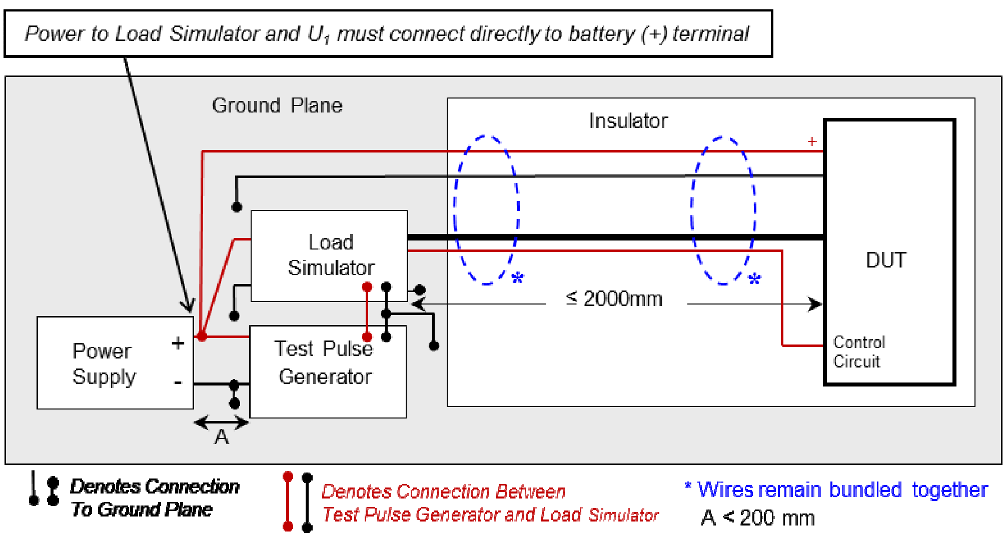
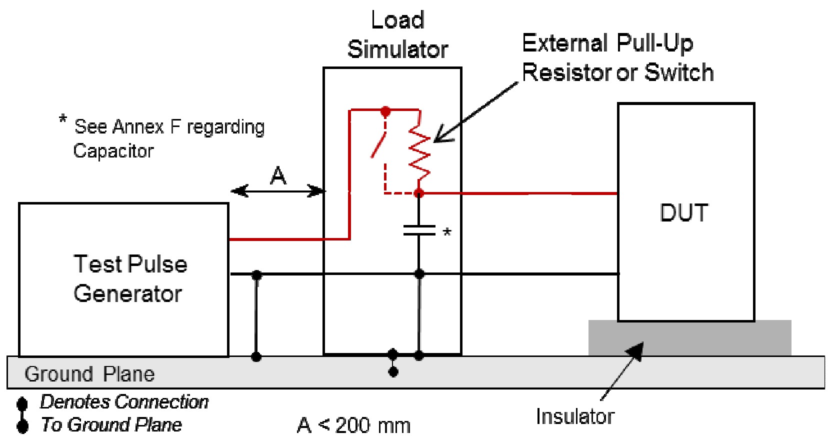


**Figure 17-4: CI 220 Test Setup Detail (Control Circuits with Remote External Pull-Up Resistor or Switch)**




## 17.3 Test Procedures

Test pulses shall be applied to power supply and control circuits documented in the EMC test plan.

Prior to testing, for Pulses A1, A2-1, A2-2, C-1 and C-2, verify that the output of the transient source (open circuit conditions) produces waveforms typical of those illustrated in Annex D. Also verify that ISO Pulse 1 meets the open circuit waveform characteristics in Figure D-6, Annex D with $U_A$ set to 13.5 volts.

a) Connect and activate the DUT. Verify that it is functioning correctly.

b) Apply each test pulse listed in Table 17-1 to each DUT battery circuit in addition to individual control circuits connected directly or indirectly to battery.

c) Monitor DUT functions before, during, and after application of each series of test pulses for the time stated in Table 17-1.

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## 18.0 Immunity from Transient Disturbances: CI 221

These requirements are related to immunity from conducted transients occurring on both switched and unswitched power supply circuits of the component and/or subsystem. This requirement is applicable only to 24 VDC applications.

### 18.1 Requirements

The function of the component/subsystem shall meet the performance requirements delineated in Table 18-1.

**Table 18-1: CI 221 Transient Immunity Requirements**

| Test Pulse # | Application | Stress Level (Volts) (1,2 | | Minimum # of pulses or Test Duration | Repetition time | Functional Performance Status |
|---|---|---|---|---|---|---|
| | | $U_A$ | $U_S$ | | | |
| 1 | Switched Power Supply Circuits | 27 | -450 | 5000 pulses | 0.5 sec | II |
| 2a | All Supply Circuit | 27 | +37 | 5000 pulses | 0.2 sec | I |
| 2b | Supply Circuits connected in parrallel with an electric motor | 27 | +20 | 10 pulses | 0.5 sec | II |
| 3a | All Supply Circuit | 27 | -150 | 1 hour | 90 msec | I |
| 3b | All Supply Circuit | 27 | +150 | 1 hour | 90 msec | I |

(1) See ISO 7637-2 for detailed test pulse characteristics.

(2) $U_S$ represents open circuit conditions.

### 18.2 Test Verification and Test Setup

Verification of component performance shall be in accordance with ISO 7637-2.

- The test harness connecting the DUT to the Load Simulator shall be ≤ 2000 mm in length.
- The wire length between the test generator and the DUT circuit under test shall be ≤ 500±100 mm for application of Pulses 3a and 3b. For other pulses, length shall be ≤ 2000 mm.
- If the DUT has multiple power (e.g. battery direct, ignition/run, relay etc), these circuits shall be configured to facilitate individual application of test pulses. Untested circuits shall be connected directly to the power supply positive terminal.
- A device powered from an external, unregulated supply located in another module shall be tested as a system with the sourcing module being subjected to the transient disturbance. Details of this setup shall be documented in the EMC test plan.

### 18.3 Test Procedures

Test pulses shall be applied to power supply and input circuits in accordance with the requirements delineated ISO 7637-2 (2004) and documented in the EMC test plan.

a) Prior to testing, verify the transient pulses meet the requirements delineated in Annex D. Reference ISO 7637-2 (2004) for additional detail concerning pulse verification.
b) Connect and activate the DUT. Verify that it is functioning correctly.
c) Apply each test pulse listed in Table 18-1individually to each DUT battery circuit.
d) Monitor DUT functions before, during, and after application of each series of test pulses for the time stated in Table 18-1.
e) All test pulses shall be measured during application to the DUT and documented in the test report

## 19.0 Immunity from Load Dump: CI 222

These requirements are related to immunity from conducted transients that can occur in the event of a discharged battery becoming disconnected while the alternator is generating charging current and with other electrical loads still connected. This is commonly referenced as a "Load Dump" condition. The requirements apply to both 12 and 24 VDC systems.

### 19.1 Requirements

The function of the component/subsystem shall meet the performance requirements delineated in Table 19-1. Pulse 5a simulates applications where Central Load Dump protection in the alternator is not present. Pulse 5b simulates applications where Central Load Dump protection in the alternator is present. Selection of the correct test pulse shall be reviewed/approved by the FMC EMC department and documented in the EMC test plan.

**Table 19-1: CI 222 Load Dump Requirements**

| ISO Test Pulse | Application | Stress Level ( Volts ) | | | | | Minimum # of pulses | Repetition time | Functional Performance Status | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 12 VDC System | | | 24 VDC System | | | | | |
| | | $U_A$ | $U_S$ (2) | $U_S^*$ (2, 3) | $U_A$ | $U_S$ | | | Class A & B | Class C |
| 5a (1) | All power supply circuits Control circuits | 13.5 | +60 | n/a | 27 | +120 (2) | 5 | 60 sec | III | II |
| 5b (1) | All power supply circuits Control circuits | 13.5 | +30 | +21.5 (-1/+0) | n/a | | 5 | 60 sec | III | II |

(1) Selection of Pulse 5a or 5b depends on whether vehicle application includes central load dump protection. Selection shall be approved by the FMC EMC department and documented in EMC test plan

(2) $U_S$ represent open circuit conditions. See Annex D for pulse characteristics.

(3) $U_S^*$ represent clamped voltage. See Figure 19-3

### 19.2 Test Verification and Test Setup

Verification of component performance shall be in accordance with ISO 7637-2 (2004) except where noted in this specification. The test setup is shown in Figure 19-1. The transient generator is connected to both the DUT and the Load Simulator to facilitate simultaneous application to transient pulse.

- The test harness connecting the DUT to the Load Simulator and transient pulse generator shall be ≤ 2000 mm in length. Circuits may remain part of the cable harness or split out as illustrated in the setup figures below.
- The DUT and test harness shall be placed on a dielectric support 50 mm above the ground plane.
- Although normal testing requires simultaneous application of Pulse 5a or 5b, special conditions requiring testing of individual power or input circuits, shall be fully documented in the EMC test plan.
- A device powered from an external, unregulated supply located in another module shall be tested as a system with the sourcing module being subjected to the transient disturbance. Details of this setup shall be documented in the EMC test plan.
- ISO Pulse 5a, when applied to 12 VDC systems requires modification of the ISO transient generator to place a 0.5 ohm resistor externally across the Test Pulse Generator. This modification is shown in Figure 19-2. The resistor connection shall be within 200 mm of the ISO transient generator output terminals. The wattage value of the resistor shall be sized to be compatible with the DC voltage plus the transient voltage magnitude. The 0.5 ohm resistor is not present when testing is performed on 24 VDC systems.

- ISO Pulse 5b (applied to 12 VDC systems only) requires additional modification to include the 0.5 ohm resistor plus a diode bridge, which is designed to yield the voltage waveform shown in Figure D-12 of Annex D. The resistor and diode bridge shall be located within 200 mm of the ISO transient generator output terminals. This is illustrated in Figure 19-3.

**Figure 19-1: CI 222 Test Setup**

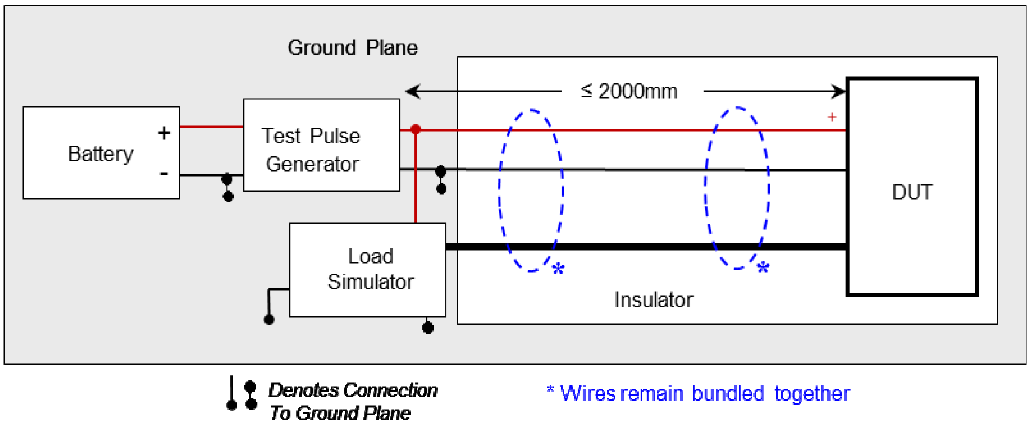
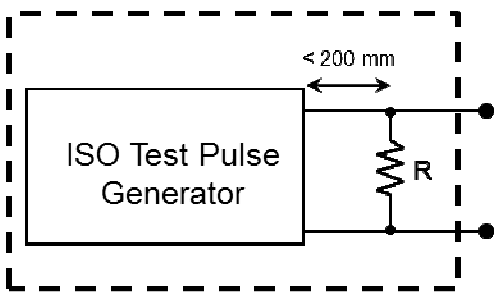
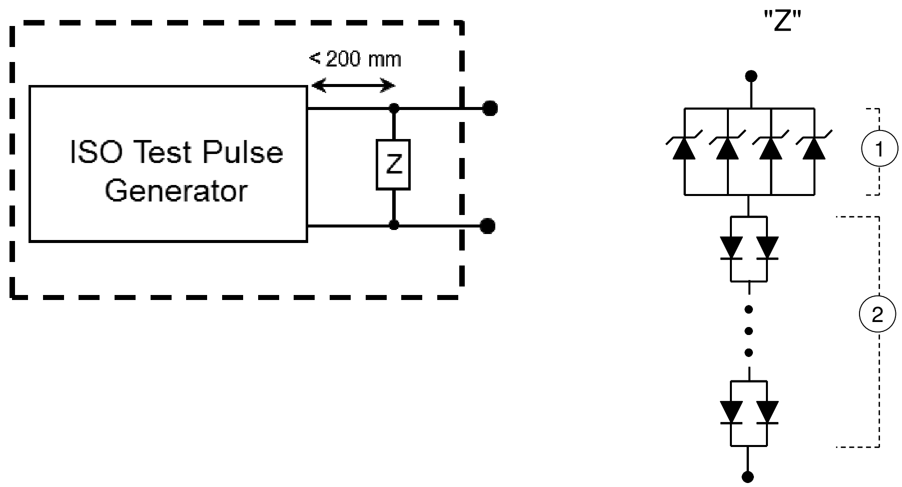



**Figure 19-2: Test Pulse Generator for Application of Pulse 5a (12 VDC Applications only )**




R= 0.5 ohms

**Figure 19-3: Test Pulse Generator Modification for Application of Pulse 5b**




1. Zener diode: MR 2535L 2. Diode: 1N 5404

Diode configuration adjusted to yield voltage characteristics shown in Figure D-12 of Annex D.

## 19.3 Test Procedures

Testing with Pulse 5a:

a) For Pulse 5a adjust the transient generator to the voltage level, $U_S$, listed in Table 19-1 under open circuit conditions (no DUT present, $R_L$ = open circuit). Pulse measurement shall be facilitated using an oscilloscope and voltage probe meeting the requirements delineated in ISO 7637-2. Verify the pulse characteristics match those shown for the open circuit conditions in Figure D-11of Annex D. Pulse verification is performed with $U_A$ present.

b) Repeat a) under loaded conditions

   - $R_L$ = 0.5 ohms (12 VDC systems)
   - $R_L$ = 1 ohms (24 VDC systems)

   Verify the pulse meets the pulse characteristics shown for loaded conditions in Figure D-11 from Annex D.

c) Connect and activate the DUT. Verify that it is functioning correctly. For 12 VDC systems, $R_L$ shall remain connected in parallel with the DUT. $R_L$ is not present when testing 24 VDC systems.

d) Apply Pulse 5a simultaneously to the DUT's power and all of its control circuits that are externally pulled up to supply voltage (pull up loads contained within Load Simulator).

e) If required by the test plan, repeat testing selected control circuits deactivated (circuits identified to be on switched power).

f) Monitor DUT functions before, during, and after application of each series of test pulses for the time stated in Table 19-1.

g) All test pulses shall be measured during application to the DUT and documented in the test report

Testing with Pulse 5b (12 VDC systems only):

a) Repeat steps a) and b) from Pulse 5a adjustment above.

b) Connect the Zener diode network and verify the pulse meets the pulse characteristics shown in Figure D-12 from Annex D.

c) Repeat steps c) through g) from Pulse 5a above.

## 20.0 Immunity from Power Cycling: CI 230

The component shall be immune from voltage fluctuations, which occur during initial start of the vehicle's engine under cold temperature conditions. This requirement is not representative of conditions where a warm engine is restarted. These requirements are limited to 12 VDC applications.

### 20.1 Requirements

The voltage waveform requirements are illustrated in Figure 20-1. Specific application of these waveforms is dependent on the method used to connect the component's power supply and control circuits. Application requirements for each waveform are listed in Table 20-1 along with the performance requirements for the component.

**Table 20-1: CI 230 Power Cycling Requirements**

| Waveform (1) | Application | Duration | Functional Performance Status |
|---|---|---|---|
| A | Switched Power & control circuits that are activated at initiation and duration of the start and run event | 2 cycles separated by cooling period<br>(see section 20.3) | II |
| B | Power circuits connected directly to Battery (i.e. unswitched) | | II |

1) Waveforms applied simultaneously to all power supply and control circuits.

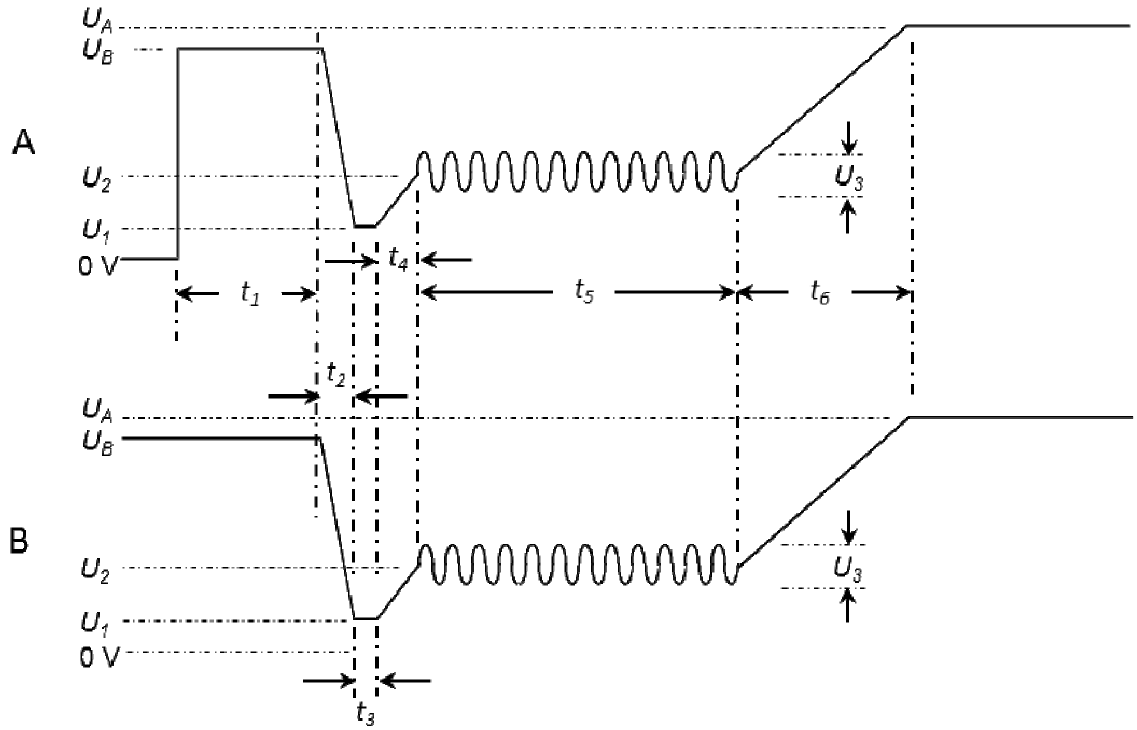
2) Any degradation in performance shall not inhibit the ability of the vehicle to start.

### 20.2 Test Verification and Test Setup

Testing shall be performed using the test Setup shown in Figure 20-2.

- The test harness connecting the DUT to the Load Simulator and transient pulse generator shall be < 2000 mm in length.
- Power to the DUT and Load Simulator is provided by Signal Sources A and B. Circuits within the Load Simulator shall be identified in the EMC test plan as to which signal source they will be powered from.
- Testing shall be performed with the DUT placed in a thermal chamber with the ability to facilitate testing at -40 +0 / -5 degrees C or the coldest temperature specified in component's engineering specification. The temperature shall be documented in the EMC test plan.
- The DUT shall be placed on a dielectric support 50 mm above the metal floor of the thermal chamber.

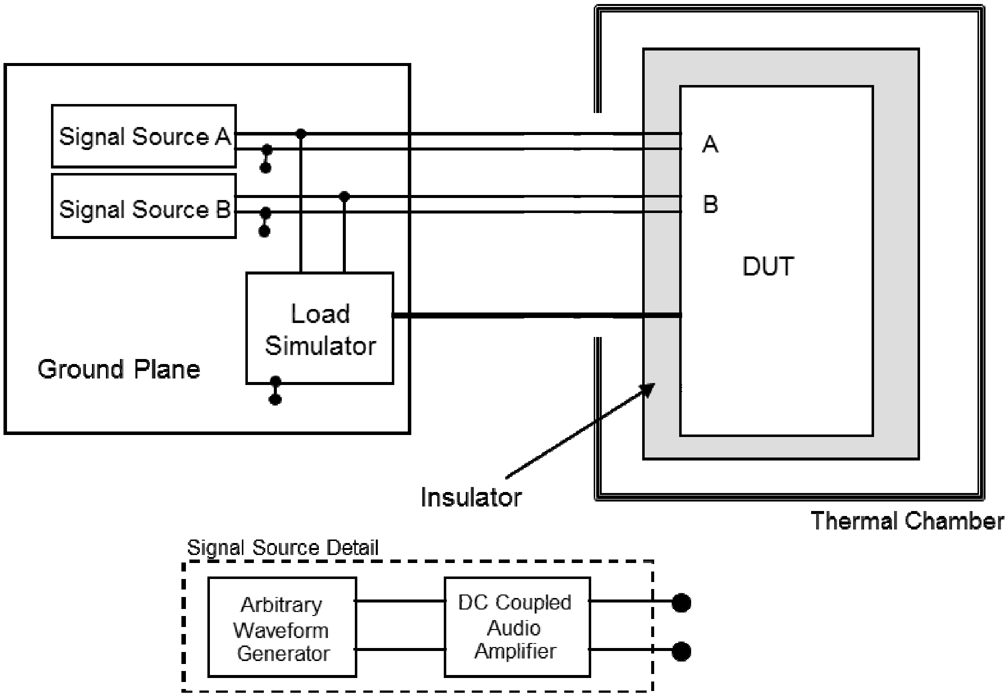
**Figure 20-1: CI 230 Power Cycling Waveforms and Timing Sequence**




**Key:**

| | | |
|---|---|---|
| $t_1$ = 200 msec | $t_5$ = 10 sec | $U_1$ = 5 V |
| $t_2$ = 5 msec | $t_6$ = 500 msec | $U_2$ = 9 V |
| $t_3$ = 15 msec | $U_A$ = 13.5 V | $U_3$ = 2 Vp-p @ 4 Hz |
| $t_4$ =50 msec | $U_B$ = 12.5 V | |

**Figure 20-2: CI 230 Power Cycling Test Setup**




## 20.3 Test Procedures

All waveforms shall be applied simultaneously to all power supply and control circuits in accordance with the timing sequence shown in Figure 20-1.

a) Verify the waveforms prior to application to the DUT.

b) Initially power the DUT and verify normal function following startup.

c) Deactivate all DUT switched power circuits in addition to any circuits in the Load Simulator that normally share the same switched power circuit (e.g. Ignition). If the DUT and/or Load Simulator contains direct power connections to battery, those circuits shall remain powered.

d) Soak the DUT at the coldest operating temperature specified in component's engineering specification or at -40 +0 / - 5 degrees C for at least 60 minutes prior to testing unless otherwise stated in the EMC test plan. See section 17.2 for details.

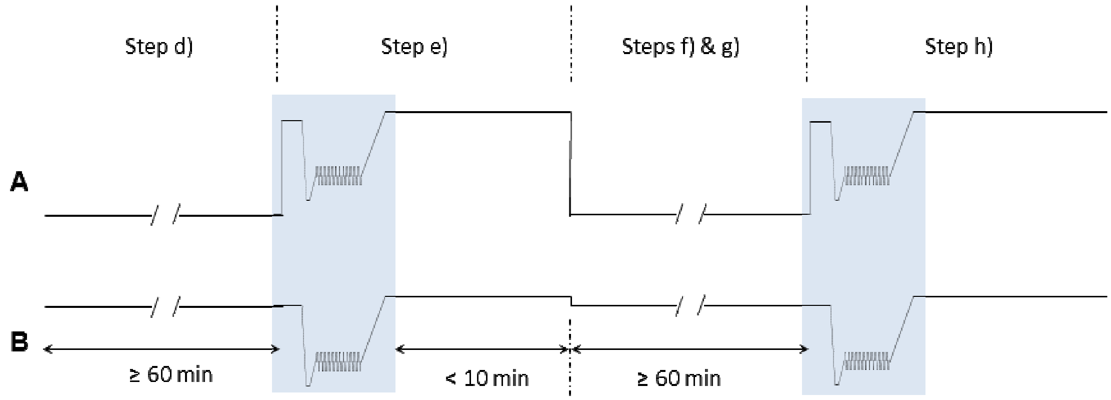
e) With the DUT remaining in the thermal chamber, apply the test waveform(s) illustrated in Figure 20-1. Upon completion of the waveforms, verify the DUT is functioning in a manner consistent with initial activation. For some DUTs, this may require an additional button press (e.g. heated seat activation). Functional verification must be completed within 10 minutes after waveform application. Monitor and record the time taken to perform the functional verification.

f) When functional verification is complete repeat step c).

g) Without disturbing the DUT (i.e DUT not removed from thermal chamber), soak the DUT at the same temperature from step d) for at least 60 minutes prior to testing unless otherwise stated in the EMC test plan.

h) Repeat step e). The total test sequence is illustrated in Figure 20-3

**Figure 20-3 CI 230 Test Sequence**




**Note: The purpose of the test is to verify DUT startup at cold temperature. Any pre functional check of DUT function shall occur <u>before</u> cold soak begins. The next activation of the DUT is when the waveforms are being applied.**

## 21.0 Immunity from Power Cycling: CI 231

This requirement is related to immunity from voltage fluctuation during starting of the vehicle's engine.. This requirement is applicable only to 24 VDC applications.

### 21.1 Requirements

The requirement is shown in Figure 21-1.

### 21.2 Test Verification and Test Setup

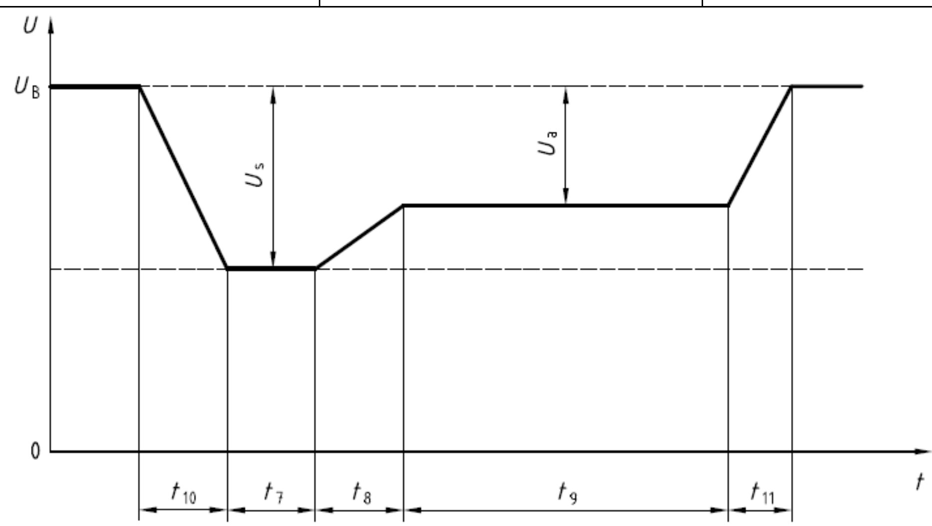
Verification of component performance shall be in accordance with ISO 7637-2 (2004). Testing is performed at room temperature therefore does not require use of a thermal chamber. The test setup shall be documented in the EMC test plan.

### 21.3 Test Procedures

All waveform shall be applied simultaneously to all DUT power supply circuits in accordance with the timing sequence shown in Figure 21-1. Verify waveforms prior to application to the DUT.

**Figure 21-1: CI 231 Power Cycling Requirements**

| Application | Duration | Functional Performance Status (1) |
|---|---|---|
| Switched & Unswitched Battery Circuits | 2 cycles separated by 1 min (2) | II |




**Key:**

| $U_B$ | $U_S$ | $U_a$ | $R_i$ | $t_7$ | $t_8$ | $t_9$ | $t_{10}$ | $t_{11}$ |
|---|---|---|---|---|---|---|---|---|
| 24 V | -12V | -7 | < 0.02Ω | 50 msec | ≤ 50 msec | 10 sec | 10 msec | 100 msec |

(1) Any degradation in performance shall not inhibit the ability of the vehicle to start.

(2) Duration must be long enough to evaluate DUT function after startup

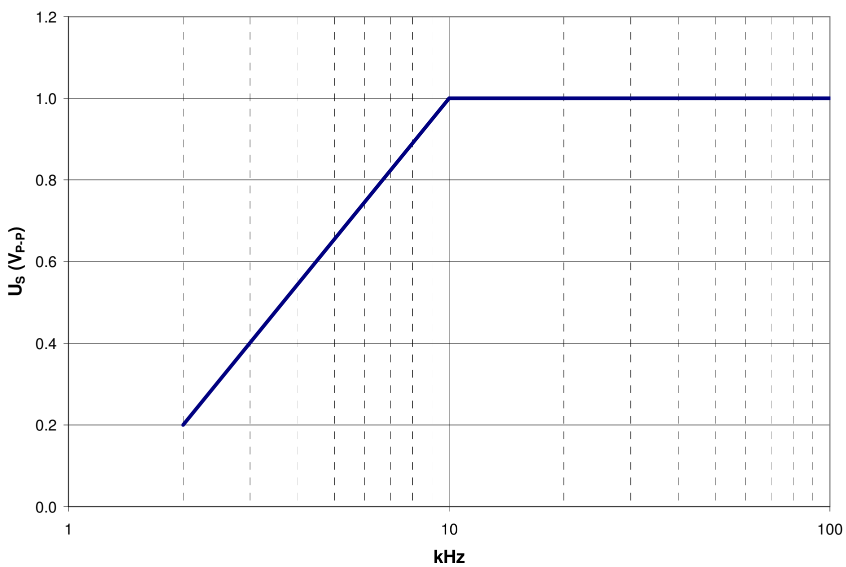
## 22.0 Immunity to Ground Voltage Offset: CI 250

The function of the component/subsystem shall be immune from sinusoidal ground offset voltages covering the frequency range from 2 kHz to 100 kHz.

### 22.1 Requirements

The function of the component/subsystem shall operate without deviation (Status I) when exposed to continuous sinusoidal electromagnetic disturbances shown in Figure 22-1 in addition to the transient sinusoidal disturbances shown in Figures 22-2 through 22-4. Delay times for the four sequences are listed in Table 22-1.

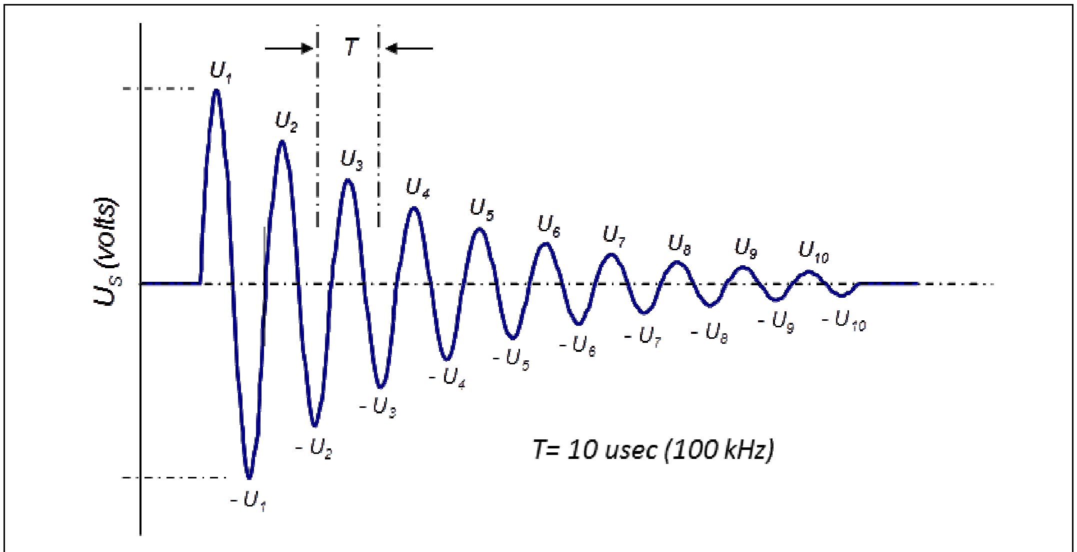
**Figure 22-1: CI 250 Requirements (Continuous Disturbances)**




| **Frequency Range** (kHz) | $U_S$ ( $V_{P\text{-}P}$ ) |
|---|---|
| 2 – 10 | $1.0 + 1.14\log\left(f/10\right)$ |
| 10 – 100 | 1.0 |

*f* = frequency in kHz

**Figure 22-2: CI 250 Transient Pulse Detail**




| | | | | |
|---|---|---|---|---|
| $U_1 = 5.00$ | $U_3 = 2.67$ | $U_5 = 1.42$ | $U_7 = 0.76$ | $U_9 = 0.41$ |
| $U_2 = 3.65$ | $U_4 = 1.95$ | $U_6 = 1.04$ | $U_8 = 0.55$ | $U_{10} = 0.30$ |

$F(Hz) = 100x10^3$ *(100 kHz)*

**Figure 22-3: CI 250 Transient Pulse Delay Detail**

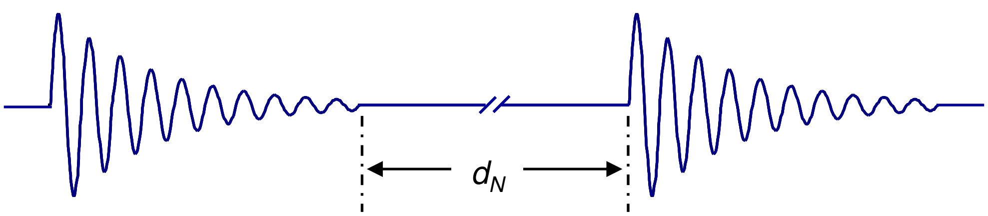


**Figure 22-4: CI 250 Requirements (Transient Disturbance Sequence)**

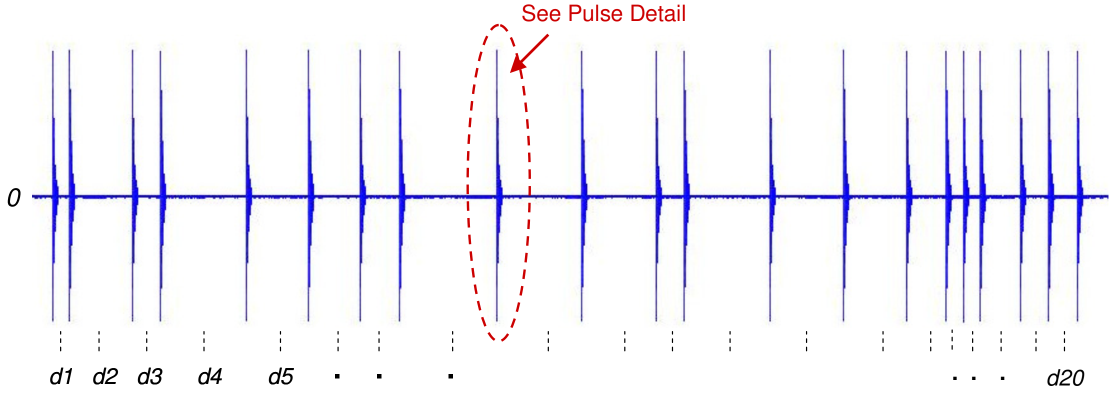



**Table 22-1: CI 250 Delay Time Sequences 1 - 4**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sequence 1 | d1 | 0.1 ms | d6 | 0.4 ms | d11 | 0.2 ms | d16 | 0.1 ms |
| | d2 | 0.5 ms | d7 | 0.3 ms | d12 | 0.3 ms | d17 | 0.1 ms |
| | d3 | 0.2 ms | d8 | 0.4 ms | d13 | 0.6 ms | d18 | 0.3 ms |
| | d4 | 0.7 ms | d9 | 0.6 ms | d14 | 0.5 ms | d19 | 0.4 ms |
| | d5 | 0.5 ms | d10 | 0.6 ms | d15 | 0.3 ms | d20 | 0.2 ms |
| Sequence 2 | d1 | 0.2 ms | d6 | 0.8 ms | d11 | 0.4 ms | d16 | 0.2 ms |
| | d2 | 1.0 ms | d6 | 0.6 ms | d12 | 0.6 ms | d17 | 0.2 ms |
| | d3 | 0.4 ms | d8 | 0.8 ms | d13 | 1.2 ms | d18 | 0.6 ms |
| | d4 | 1.4 ms | d9 | 1.2 ms | d14 | 1.0 ms | d19 | 0.8 ms |
| | d5 | 1.0 ms | d10 | 1.2 ms | d15 | 0.6 ms | d20 | 0.4 ms |
| Sequence 3 | d1 | 0.5 ms | d6 | 2.0 ms | d11 | 1.0 ms | d16 | 0.5 ms |
| | d2 | 2.5 ms | d6 | 1.5 ms | d12 | 1.5 ms | d17 | 0.5 ms |
| | d3 | 1.0 ms | d8 | 2.0 ms | d13 | 3.0 ms | d18 | 1.5 ms |
| | d4 | 3.5 ms | d9 | 3.0 ms | d14 | 2.5ms | d19 | 2.0 ms |
| | d5 | 2.5 ms | d10 | 3.0 ms | d15 | 1.5 ms | d20 | 1.0 ms |
| *Sequence 4* | d1 | 1 ms | d6 | 4 ms | d11 | 2 ms | d16 | 1 ms |
| | d2 | 5 ms | d6 | 3 ms | d12 | 3 ms | d17 | 1 ms |
| | d3 | 2 ms | d8 | 4 ms | d13 | 6 ms | d18 | 3 ms |
| | d4 | 7 ms | d9 | 6 ms | d14 | 5 ms | d19 | 4 ms |
| | d5 | 5 ms | d10 | 6 ms | d15 | 3 ms | d20 | 2 ms |

*dn represents the delay between consecutive pulses*



October 07, 2016

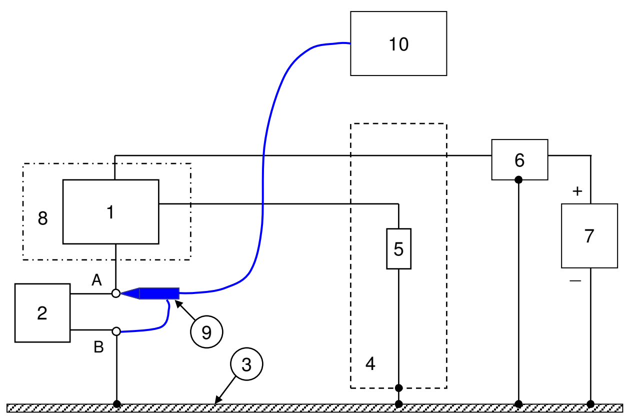
## 22.2 Test Verification and Test Setup

Testing shall be performed using either of the generic test setups shown in Figure 22-5. The specific test configuration shall be documented in the EMC test plan.

- The test harness connection between the DUT to the Load Simulator shall be $\leq$ 2000 mm. Individual ground circuits may be part of the cable harness or split out as illustrated in the figures. If the DUT has multiple ground circuits, they shall be test separately.
- Ground circuits not being tested shall be connected directly to the ground plane.
- The power supply negative terminal shall be connected to the ground plane. See section 5.54 for additional requirements for the power supply.
- The DUT and wire harness shall be placed on a dielectric support 50 mm above the ground plane.
- The source used for generation of the continuous and transient disturbances is shown in Figure 22-5.

*The signal source illustrated in Figure 22-6 includes two isolation transformers. The transformers are used to facilitate generation of the required disturbances into a 0.5 ohm load using most commercially available amplifiers. The transformers also facilitate DC isolation of amplifier from the DUT. Alternative configurations may be permitted if approved by the FMC EMC department. The signal levels illustrated in Figures 22-1 through 22-4 are generated across the 0.5 ohm resistor.*

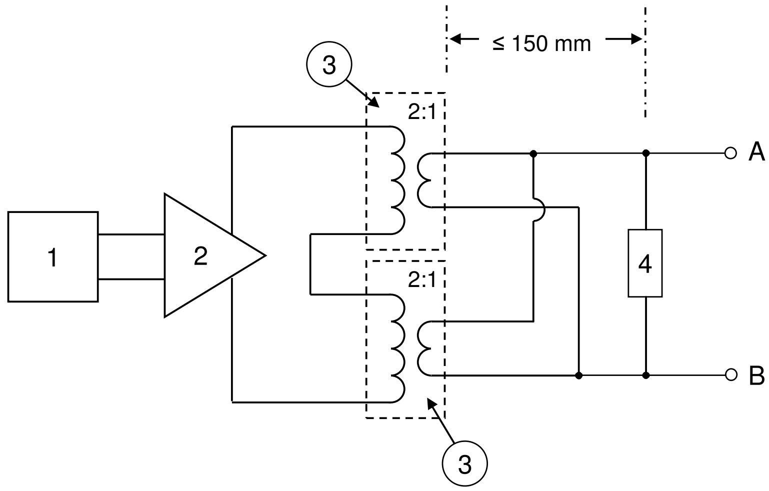
**Figure 22-5: CI 250 Test Setup for Ground Offset of DUT**




**Key:**

1. DUT
2. Signal Source (see Figure 22-6)
3. Ground Plane
4. Load Simulator
5. DUT External Load
6. Artificial Network
7. Power Supply
8. Dielectric Support
9. 10X high impedance probe (1M ohm, C< 10 pf)
10. Digital Oscilloscope (> 100 MS/s, > 6MB memory depth)

**Figure 22-6: CI 250 Signal Source Requirements**




**Key:**

1. Arbitrary Waveform Generator
2. Amplifier (recommend AE Techron 7224 or equivalent)
3. Isolation Transformer (Use Solar 6220-1A or equivalent)
4. 0.5 Ohm (250 watt) Non-Inductive Resistive Load (Dale NH-250 or equivalent)

## 22.3 Test Procedures

The waveforms shall be applied to one ground circuit at a time unless analysis demonstrates that testing each circuit individually is unnecessary. The analysis shall be documented in the EMC test plan and approved by the FMC EMC department prior to commencement of testing.

### 22.3.1 Procedure for Continuous Disturbances

a) With the DUT disconnected, adjust and record the signal generator output to generate the specified voltage level across the 0.5 ohm resistor (see Figure 22-6). Use the frequency steps listed in Table 22-3.

b) Connect the DUT and verify it is functioning correctly.

c) At each test frequency, apply the signal generator levels recorded in step a) to the DUT. The dwell time shall be at least 2 seconds. A longer dwell time may be necessary if DUT function response times are expected to be longer. This information shall be documented in the EMC test plan and test report.

d) Monitor and document any anomalies observed in DUT functionality

e) Repeat testing for all DUT operating modes listed in the EMC test plan.

**Table 22-2: CI 250 Test Frequency Requirements**

| Test Frequency Range (kHz) | Frequency Step (kHz) |
|---|---|
| 2 - 10 | 0.5 |
| 10 - 100 | 5 |

### 22.3.2 Procedures for Transient Disturbances

a) Connect the DUT and verify that it is functioning correctly in the operating mode specified in the EMC test plan.

b) Apply the test sequence shown in Figure 22-4 using delay sequence 1 while the DUT is operating. Adjust the pulse amplitude ($U_S$) to the level shown in Figure 22-2. The waveform shall be symmetrical about zero volts.

c) The test sequence shall be applied repeatedly for 60 seconds. During application of the sequence, monitor DUT function for any anomalies. If anomalies are noted, reduce the stress level to the point where normal DUT function resumes. Record the measured value of $U_S$ where this threshold occurs.

d) Repeat step b) and c) with delay sequences 2 through 4

e) Repeat steps a) through d) for all DUT operating modes listed in the EMC test plan.

## 23.0 Immunity to Voltage Dropout: CI 260

The function of the component/subsystem devices shall be immune from momentary voltage dropouts, which may occur over the life of the vehicle. Circuits affected include all power supply and control circuits.

### 23.1 Requirements

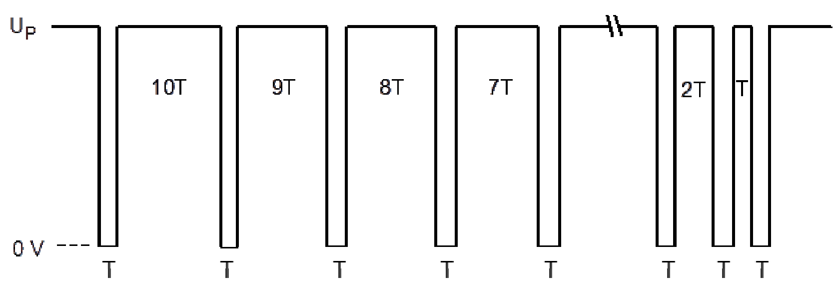
Circuits affected include all power supply and control circuits. These requirements also apply to components that are connected to a regulated power provided by another module (e.g. sensors). Requirements are listed in Table 23-1. The purpose of this test is the verification of controlled recovery of hardware and software from power interruptions.

**Table 23-1: CI 260 Voltage Dropout Requirements**

| Waveform | Application | Level | Duration | Functional Performance Status [1] | | |
|---|---|---|---|---|---|---|
| | | | | Class A | Class B | Class C |
| A Voltage Dropout: High | All Power Supply and Control Circuits | See Figure 23-1 | 3 cycles separated by 20 s | II | II | II |
| B Voltage Dropout: Low | All Power Supply and Control Circuits | See Figure 23-2 | 3 cycles separated by 20 s | II | II | II |
| C Single Voltage Dropout | All Power Supply and Control Circuits | See Figure 23-3 | 3 cycles separated by 20 s | I | I | I |
| D Voltage Dip | All Power Supply and Control Circuits | See Figure 23-4 | 10 cycles separated by 20 s | II | II | II |

1 Performance Status checked after each waveform cycle (applies to Status II response only)

**Figure 23-1: CI 260 Waveform A (Voltage Dropout: High)**



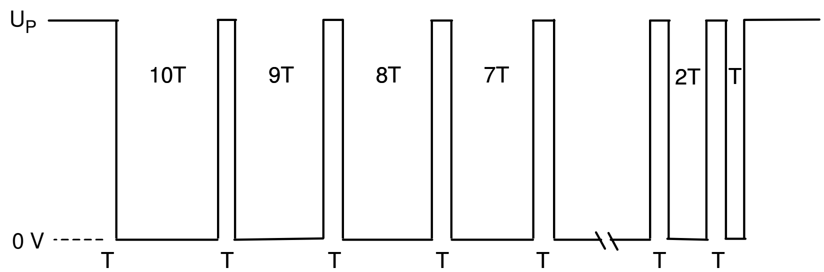

**Key:**

| | Power from Vehicle Battery | | | | Regulated Power from another Module | | | |
|---|---|---|---|---|---|---|---|---|
| $U_P$ | 13.5V, 27V [2] | | | | Nominal Supply Voltage (e.g. 5 Vdc, 3 Vdc) | | | |
| T [1] | 100 us | 300 us | 500 us | 2 ms | 100 us | 300 us | 500 us | 2 ms |
| | 5 ms | 10 ms | 30 ms | 50 ms | 5 ms | 10 ms | 30 ms | 50 ms |

(1) Waveform transition times are approximately 10 us

(2) Voltage selected dependent on use of 12 or 24 VDC systems

**Figure 23-2: CI 260 Waveform B (Voltage Dropout: Low)**



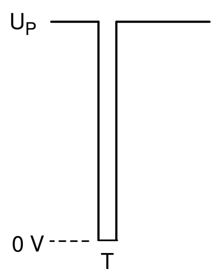

**Key:**

| | Power from Vehicle Battery | | | | Regulated Power from another Module | | | |
|---|---|---|---|---|---|---|---|---|
| $U_P$ | 13.5V, 27V [2] | | | | Nominal Supply Voltage (e.g. 5 Vdc, 3 Vdc) | | | |
| T [1] | 100 us | 300 us | 500 us | 2 ms | 100 us | 300 us | 500 us | 2 ms |
| | 5 ms | 10 ms | 30 ms | 50 ms | 5 ms | 10 ms | 30 ms | 50 ms |

(1) Waveform transition times are approximately 10 us

(2) Voltage selected dependent on use of 12 or 24 VDC systems.

**Figure 23-3: CI 260 Waveform C (Single Voltage Dropout)**



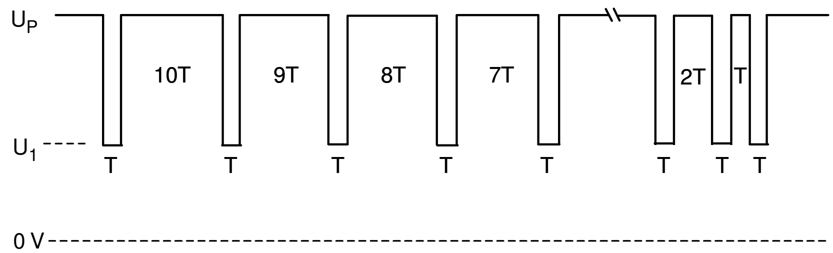

**Key:**

| | Power from Vehicle Battery | | | Regulated Power from another Module | | |
|---|---|---|---|---|---|---|
| $U_P$ | 13.5V, 27V [2] | | | Nominal Supply Voltage (e.g. 5 Vdc, 3 Vdc) | | |
| T [1] | 100 us | 300 us | 500 us | 100 us | 300 us | 500 us |

(1) Waveform transition times are approximately 10 us

(2) Voltage selected dependent on use of 12 or 24 VDC systems

**Figure 23-4: CI 260 Waveform D (Voltage Dip)**




**Key:**

| | Power from Vehicle Battery | | | | Regulated Power from another Module | | | |
|---|---|---|---|---|---|---|---|---|
| $U_P$ | 13.5V, 27V (2) | | | | Nominal Supply Voltage (e.g. 5 Vdc, 3 Vdc) | | | |
| $U_1$ | 5 V | | | | 80% of Nominal Supply Voltage | | | |
| T (1) | 100 us | 300 us | 500 us | 2 ms | 100 us | 300 us | 500 us | 2 ms |
| | 5 ms | 10 ms | 30 ms | 50 ms | 5 ms | 10 ms | 30 ms | 50 ms |

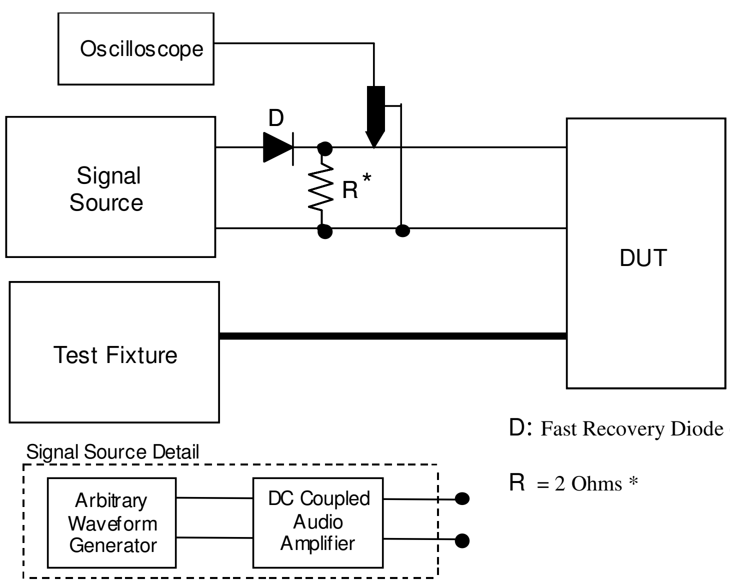
(1) Waveform transition times are approximately 10 us

(2) Voltage selected dependent on use of 12 or 24 VDC systems

## 23.2 Test Verification and Test Setup

Testing shall be performed using the test Setups shown in Figures 23-5 and 23-6. The test harness connecting the DUT to the Load Simulator and transient pulse generator shall be ≤ 2000 mm in length.

**Figure 23-5: CI 260 Test Setup Detail for Waveforms A, B and C**

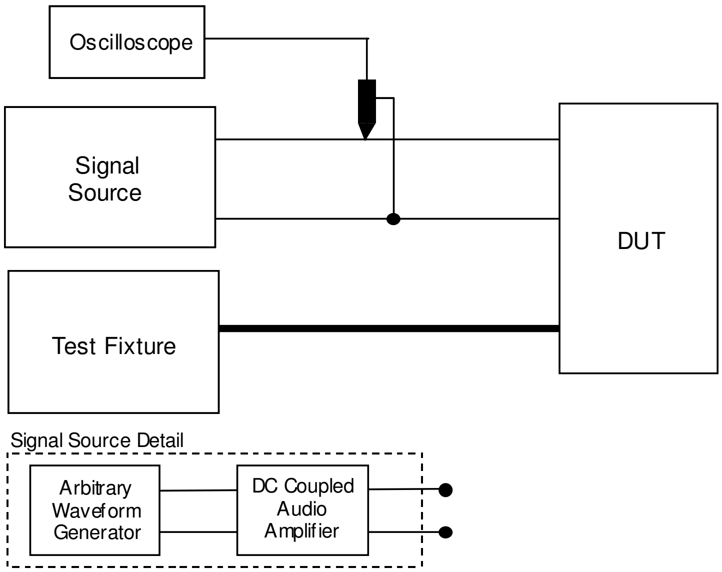



D: Fast Recovery Diode (e.g. MUR 3080)

R = 2 Ohms *

** The resistor value may be increased when testing components powered from a regulated supply (category AS). The value of this resistor shall be mutually agreed to by the FMC EMC department and the component's D&R activity. The resistance value shall be documented in the component's EMC test plan.*

**Figure 23-6: CI 260 Test Setup Detail for Waveform D**




## 23.3 Test Procedures

a) Prior to testing, without the DUT connected, adjust DC level $U_P$ of the signal generator/audio amplifier to either 13.5 or 26 volts (dependent on 12, 24VDC system) or to the regulated voltage specified in the test plan.

b) Activate measure and verify that each of the test waveforms A, B, C, and D match those waveforms illustrated in section 19.2.

c) Connect and activate the DUT. Verify that it is functioning correctly (only $U_P$ present)

d) Apply each waveform into each power supply and control circuit separately

e) Application of the waveforms shall be in accordance with the requirements delineated in Table 23-1. Monitor DUT functions before, during and after application of each test waveform.

f) Repeat testing for all DUT operating modes listed in the test.

## 24.0 Immunity to Voltage Overstress: CI 270

The function of the component/subsystem shall be immune from DC voltage overstress conditions that may occur during the assembly process, potential failure of the alternator regulator or assisted starting (i.e. jump start) with a 24 VDC supply. These requirements are applicable only to 12 VDC systems.

### 24.1 Requirements

The component shall be immune from potential voltage overstress. This requirement is applicable to all power supply or control circuits, either switched to, or directly connected to battery. The requirement is also applicable to control circuits directly connected to switched battery connections or through an external pull-up resistor. Requirements are delineated in Table 24-1. This requirement may be waived if analysis shows that the component will meet the requirements in Table 24-1. However, the FMC EMC department shall review and concur on this analysis to avoid this testing.

**Table 24-1: CI 270 Requirements for Voltage Overstress**

| Requirement | | Functional Performance Status | |
|---|---|---|---|
| **Amplitude (V)** | **Duration** | **Class A** | **Class B and C** |
| -14 (+0, -0.5) | ≥ 2 min | III | III |
| 19 (+0.95, -0) | ≥ 60 min | III | II |
| 27 (+0, -1) | ≥ 60 sec (1) | III | II |

1. For devices connected only to the start circuit, the duration time may be reduced to 15 sec.

### 24.2 Test Setup and Verification

The DUT and any electronic hardware in the Load Simulator shall be powered from a DC power supply (see paragraph 5.5.4 for requirements). For these tests, the power supply shall have minimum short circuit capacity of 100 amperes.

A device that is reverse battery protected with a fused power circuit and a reverse biased diode in parallel with the device shall be tested in a configuration representative of the vehicle. Example: If a vehicle fuse is used to protect the device, testing shall be performed with the same fuse type. The fuse type shall be documented in the component engineering specification and the EMC test plan.

### 24.3 Test Procedures

a) Apply –14 volts only to power circuits with direct battery connections. After 60 seconds, the same potential shall then be applied to the remaining switched power and control circuits for 60 seconds while maintaining the same potential on the direct battery connections. After completion of this test, apply normal +13.5 volts and verify that the DUT powers up and functions properly.

b) Repeat step a) with 27 volts. Duration time may be reduce to 15 seconds if the DUT is normally connected to the vehicle start circuit. This shall be documented in the EMC test plan.

c) Apply +19 volts to all power and control circuits. All circuits shall be tested simultaneously. Verify functionality per Table 24-1.

## 25.0 Electrostatic Discharge: CI 280

The function of the component/subsystem devices shall be immune from overstress due to Electrostatic Discharge (ESD). CI 280 shall be performed before any other required testing. See section 6.3 for additional details.

### 25.1 Requirements

- The component shall be immune to ESD events that occur during normal handling and assembly. These requirements are listed in Table 25-1.
- The component shall be immune to ESD events that can occur during normal operation (i.e. powered). These requirements are listed in 25-2. This includes components in direct access from within the passenger compartment or trunk, or by direct access through an open window from a person outside the vehicle (e.g. door locks, turn signal stalk). The requirement also covers components that are not directly accessible.

**Table 25-1: CI 280 ESD Requirements: Handling (unpowered)**

| Discharge Sequence | Type of Discharge | Test Voltage Level | Minimum Number of Discharges at each polarity | Functional Performance Status | | |
|---|---|---|---|---|---|---|
| | | | | Class A | Class B | Class C |
| 1 | Contact discharge C = 150 pF, R = 2kΩ | ± 4 kV | 3 | IV | | |
| 2 (1) | Contact discharge C = 150 pF, R = 2kΩ | ± 6 kV | 3 | | | |
| 3 (1) | Air discharge C = 150 pF, R = 2kΩ | ± 8 kV | 3 | | | |

1. This sequence is not applicable to connector pins

### 25.2 Test Verification and Test Setup

Testing shall be performed in accordance with ISO 10605-2008 except where noted in this specification. The test facility shall be maintained at an ambient temperature at (23 ±5) °C and a relative humidity from 20 % to 40 %

**Table 25-2: CI 280 ESD Requirements: Powered (all component surfaces)**

| Discharge Sequence | Type of Discharge | Test Voltage Level | Minimum Number of Discharges at each polarity | Functional Performance Status | | |
|---|---|---|---|---|---|---|
| | | | | Class A | Class B | Class C |
| 1 | Air discharge C = 330 pF, R = 2kΩ | ± 4 kV | 3 | I | | |
| 2 | Contact discharge C = 330 pF, R = 2kΩ | ± 4 kV | 3 | | | |
| 3 | Air discharge C = 330 pF, R = 2kΩ | ± 6 kV | 3 | | | |
| 4 | Contact discharge C = 330 pF, R = 2kΩ | ± 6 kV | 3 | II | | |
| 5 | Air discharge C = 330 pF, R = 2kΩ | ± 8 kV | 3 | | | |
| 6 | Contact discharge C = 330 pF, R = 2kΩ | ± 8 kV | 3 | | | |
| 7 (1) | Air discharge C = 330 pF, R = 2kΩ | ± 15 kV | 3 | | | |
| 8 (2) | Air discharge C = 150 pF, R = 2kΩ | ± 25 kV | 3 | | | |

1. This sequence is limited to devices physically accessible in the passenger compartment and trunk.
2. This sequence is applicable only to device surfaces that are directly accessible from outside the vehicle (e.g. keyless entry) or interior surfaces without touching any portion of the vehicle. (e.g. door lock switches, head lamp switch, cluster).

### 25.2.1 Handling Tests

Handling Tests simulates exposure to static discharging due to connecting a device to a potentially charged harness during the vehicle build process. The setup is illustrated in Figure 25-1. The DUT shall be placed directly on a dielectric support that is 50 mm in height. All DUT power return and logic return terminals shall be connected to the ground plane via wires with a maximum length of 200 mm. For those devices (such as switches with backlighting LEDs, etc.), which are connected to ground through a module (such as a body controller, HVAC control module, etc.), attach the output (that would normally be connected to a controller I/O) to the ground.

### 25.2.2 Powered Tests

Figure 25-2 illustrates the standard Setup used when the DUT is powered and functioning.

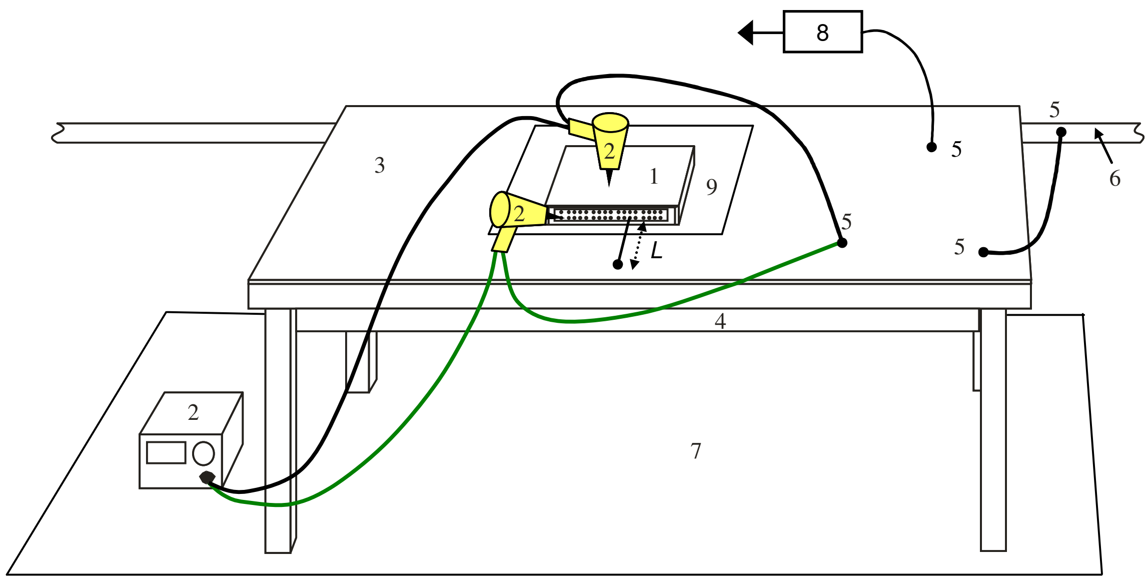
The DUT and its attached test harness shall be placed on a clean, dielectric support ($\varepsilon_r \leq 1.4$) support that is 50mm thick. The dielectric lies directly on the ground plane. The test harness connecting the DUT and Load Simulator shall be 1700 mm (+300 / -0 mm) in length. The Load Simulator shall be connected directly to the ground plan. If the outer case of the DUT is metal and can be grounded when installed in the vehicle, the DUT it shall be placed directly on the ground plane.

If there is uncertainty about how the DUT is installed in the vehicle, the DUT shall be tested in both configurations. The ground plane shall be attached to the negative terminal of the battery and to test facility ground. *As an alternative, the battery may be place on the floor of the facility.*

If the DUT has remote inputs that are accessible by the operator (e.g. switches) or communications bus circuits accessible via diagnostic connectors the associated circuit wires shall be split out of the main harness and terminated with representative switches and/or connectors (See Figure 25-2). Wiring for communication bus circuits (e.g. CAN) shall be configured such that the wiring is routed and connected directly to DUT. This requirement is illustrated in Figure 25-3.

Details of these remote connections shall be documented in the EMC test plan and approved by the FMC EMC department prior to commencement of testing. Detailed characteristics of switches and connectors to be used for testing shall be included in the EMC test plan.

**Figure 25-1: CI 280 ESD Handling Test Setup**




*L ≤ 200 mm*

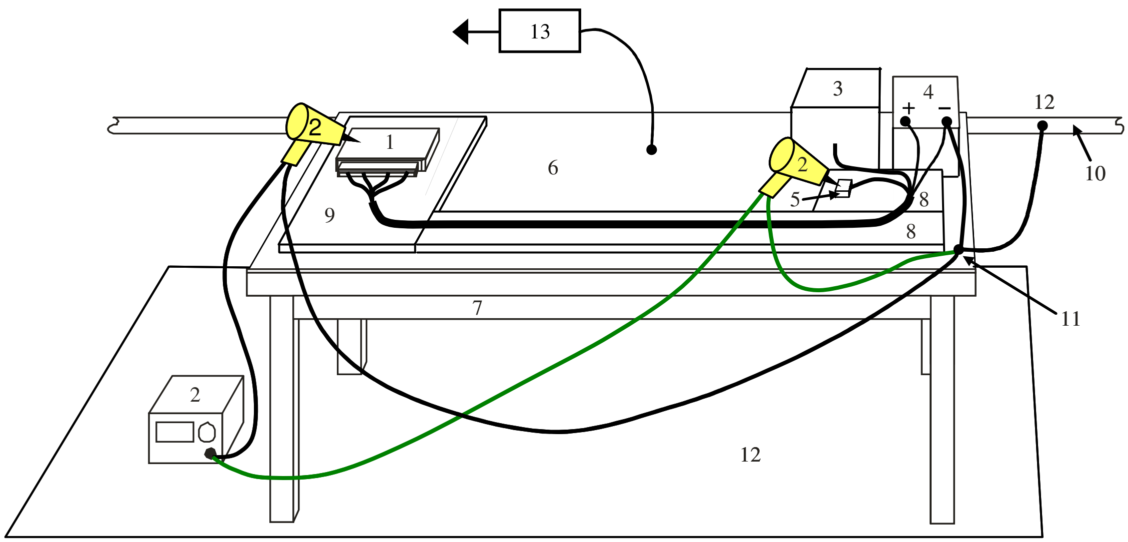
**Key**

1. DUT
2. ESD Simulator
3. Ground Plane
4. Wooden Table

L: Ground Wire Length ≤ 200 mm. (Only used during application of ESD to connector pins)

5. Ground Plane Connection
6. Test Facility Ground connection
7. Floor of Test Facility
8. ~ 1 Meg ohm bleed-off Resistor
9. Dielectric Support

**Figure 25-2: CI 280 ESD Powered Test Setup**



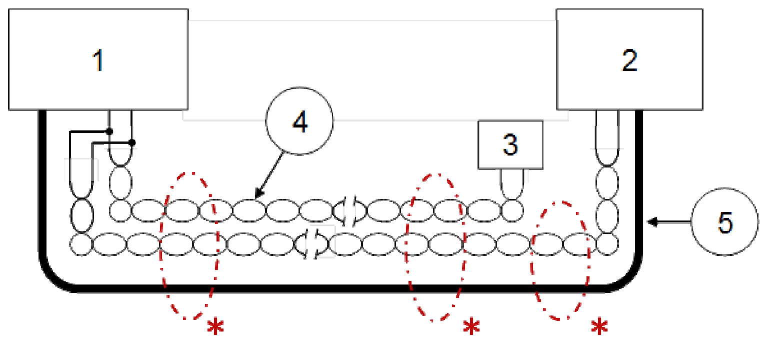

**Key**

1. DUT
2. ESD Simulator
3. Load Simulator
4. Power Supply (see section 5.5.4)
5. Remote Switch and/or Diagnostic Connector
6. Ground Plane
7. Wooden Bench
8. Harness Dielectric Support
9. DUT Dielectric Support (if needed)
10. Test Facility Ground
11. Ground Plane Reference Termination
12. Ground Plane Connection
13. ~ 1 Meg ohm bleed-off Resistor

## 25.3 Test Procedures

- Testing shall be performed sequentially starting with handling tests followed by powered and direct access tests. Before testing commences, the discharge voltage of the ESD simulator shall be verified at the levels listed in Tables 25-1 and 25-2.
- Between individual discharges, the remaining charge shall be bled off using the bleed-off resistor (approximately 1M ohm resistance) by touching the discharge point and the ground plane. This step is particularly critical for devices with decorative chrome trim.
- Charge dissipation between discharges of some modules (instrument panels, large plastic modules etc.) may require use of an ionizer. If used, the air ionizer shall be turned off and removed before each discharge is applied.
- DUT functionality shall be checked following each discharge event (powered testing)
- When testing is completed, measurements should be performed to verify that the DUT I/O parametric values (e.g. resistance, capacitance, leakage current, etc.) remain within their specified tolerances, but only if those measurements can be performed at the same test facility. Alternatively, parametric measurements shall be performed upon completion of all EMC testing listed in the test plan. Although not required, it is recommended that ESD testing be performed on additional test samples to facilitate parametric testing before EMC testing is completed.

**Figure 25-3: CI 280 Test setup ( Communication Bus Connection Requirements )**




**Key**

1. DUT
2. Load Simulator
3. Diagnositic Connector (e.g. OBDII)
4. Diagnositic Wiring (e.g. CAN) *wiring shown is twisted and same length as DUT harness.*
5. Other DUT circuits

* CAN wiring shown remains co-bundled with other wiring within test harness (see Figure 25-2)

### 25.3.1 Handling (Unpowered) Tests

Before testing commences, the discharge voltage of the ESD simulator shall be verified at the levels listed in Table 25-1.

a) Apply ±4 kV contact discharge (sequence #1) to all DUT connector pins *(discharge sequence 2 and 3 are not applied).* If connector body is non-metallic and the connector pins are recessed, an extension contact (< 25 mm) shall be installed to facilitate testing of the individual pins. If the connector body is metallic with recessed pins, extension contacts shall not be installed.

b) Apply contact and air discharges according to the sequence shown in Table 25-1 on all exposed shafts, buttons, switches, and/or surfaces (including along all air gaps that exist between buttons, faceplates, etc.) that are a result of the design of the product. All discharge points shall be specified in the EMC test plan.

### 25.3.2 Powered Tests

All tests shall be performed while the DUT is in operation using the voltage levels and ESD network values listed in Table 25-2. Testing shall be limited to one DUT operating mode (specified in EMC test plan). Monitoring instrumentation and methods to determine DUT performance during testing shall be documented in the test report. Monitoring of particular DUT functions must not disturb its operation or couple in any of the ESD simulator discharge energy that the DUT would not normally experience. Also, steps should be taken to preclude potential damage of monitoring equipment during testing.

a) Verify that the DUT is fully operational. If the DUT contains network functions (e.g. J1850, CAN, LIN), normal expected network traffic shall be simulated to represent that typical in the vehicle application. Details regarding specific network traffic messages, bus utilization etc, shall be documented in the EMC test plan.

b) Perform contact and air discharges per Table 25-2 (sequence 1 through 6) to each exposed shaft, button, switch and/or surface of the DUT including air gaps that exist between buttons, faceplates, etc. that are a result of the design of the product. All discharge points shall be documented in the EMC test plan. For each of the required discharge voltages, three (3) discharges of positive and three (3) discharges of negative polarity shall be applied at each of the specified discharge points.

c) Repeat step b) using discharge sequence 7 if the DUT is physically accessible in the passenger compartment or trunk.

d) Repeat steps b) and c) for DUT remote inputs that are accessible by the operator (e.g. switch inputs). A representative switch may be used, but shall be approved by the FMC EMC department in writing prior to commencement of testing.

e) Repeat step b) and c) for DUT communications bus circuits accessible via diagnostic connectors. Apply contact and air discharges directly to the connector pins as illustrated in Figure 25-2.

f) Perform air discharge ± 25 KV (sequence 8) to DUT surfaces that are:

- Located in the passenger compartment, but are only in directly access from outside the vehicle (e.g. turn signal stalk switch, window switches).
- Directly accessible from the outside of the vehicle (e.g. keyless entry keypad).

For each of the required discharge voltages, three (3) discharges of positive and three (3) discharges of negative polarity shall be applied at each of the specified discharge points. Following each discharge, verify the DUT is still functioning properly.

# Annex A (Normative): Field Calibration Procedure for ALSE Method Bands 7 and 8)

Due to the need for accurate generation of the high field strengths for Bands 7 and 8, field characterization shall be facilitated using the procedures outlined in this annex. These procedures replace those delineated in ISO 11452-2. This characterization procedure allows for use of either CW E-field probes or a receive antenna (DRG horn). For Bands 5 and 6, the field characterization delineated in ISO 11452-2 shall be used. The procedure outlined in this annex shall not be used for field characterization of Bands 5and 6.

## A.1 CW E-field Probe Method

When using this method, the orientation of the CW E-field probe axes with respect to surface of the dielectric support and the transmit antenna are specifically defined. Figures A-1 and A-2 illustrate positioning for two common probe styles. For some probes, special consideration must be given to assure they are oriented correctly. In Figure A-2, the probe handle must be tilted upward with respect to the surface bench (typically 35 degrees) and rotated around the axis normal to the bench surface (typically 135 degrees) to achieve proper alignment of the probe. Actual positioning shall be determined, based on the probe's specifications. For either probe, its phase center (probe axis origin) is 125 mm above the surface of the dielectric support, used during actual testing.

Calibration for vertical or horizontal polarization shall be relevant to the specific axis, not the vector resultant (e.g. $E_{total}$). Example: For vertical polarization, the field calibration shall be relative to the vertically aligned field probe sensor (i.e. Z axis sensor). For horizontal polarization, the field calibration shall be relative to the horizontally aligned field probe sensor (i.e. X axis sensor). Using this method requires the field probe *facilitate separate field axis readings.* Field probes that produce only a vector summation of the measured field shall not be used.

Additional requirements include:

- The phase center of the field probe is positioned 125 mm above the surface of the dielectric support used during actual testing.
- Peak forward power shall be the reference parameter for characterization of the field. This forward power shall be measured using either a peak envelope power (PEP) sensor (preferred method) or a spectrum analyzer. If a spectrum analyzer is used, it shall be tuned to each individual frequency using zero span setting with a measurement bandwidth greater than 3 MHz.

Pulse modulation characteristics shall conform to that illustrated in Figure B-1 in Annex B.

- Characterization shall be performed using CW at the required field strengths in Table 12-5. **Characterization at lower field strengths with subsequent power scaling for higher field strengths is not permitted.**
- The E-field probe used shall be capable of measuring electric fields listed in Table 12-5 (e.g. 300 / 600 V/m.
- The E-field probe shall be specifically calibrated the following frequencies:
    - 1.3 GHz
    - 2.9 GHz

## A.2 Pulsed E-field Probe Method

Use of E-field probes capable of direct measurement of a pulsed fields is permissible only with prior written approval from the FMC EMC department.. The probes shall meet the requirements delineated for CW field probes (section A.1) with the exception that measurement of CW fields is not required. Currently the only approved commercially available pulsed E-field probe is the Amplifier Research Model PL 7004.

## A.3 Antenna Method

Figure A-3 illustrates the setup when using a receiving antenna for field characterization. This method may be used when using either CW or pulsed amplifiers. This method requires use of any of the following as the receive antenna:

- ETS Lindgren DRG 3115
- Antenna Research: DRG 118/A
- Rohde & Schwarz: HF906

Use of alternative antennas shall be approved by the FMC EMC department. Additional requirements include:

- The phase center of the antenna is positioned 125 mm above the surface of the dielectric support used during actual testing.
- Peak forward power shall be the reference parameter for characterization of the field. This forward power shall be measured using either a peak envelope power (PEP) sensor (preferred method) or a spectrum analyzer. If a spectrum analyzer is used, it shall be tuned to each individual frequency using zero span setting with a measurement bandwidth greater than 3 MHz.
- Pulse modulation characteristics shall conform to that illustrated in Figure B-1 of Annex B.
- Characterization shall be performed using the required field strengths in Table 12-5. **Characterization at lower field strengths with subsequent power scaling for higher filed strengths is not permitted.**

**Figure A-1: Field Probe (Type A) Positioning Requirements (RI 114, Bands 6 and 7)**

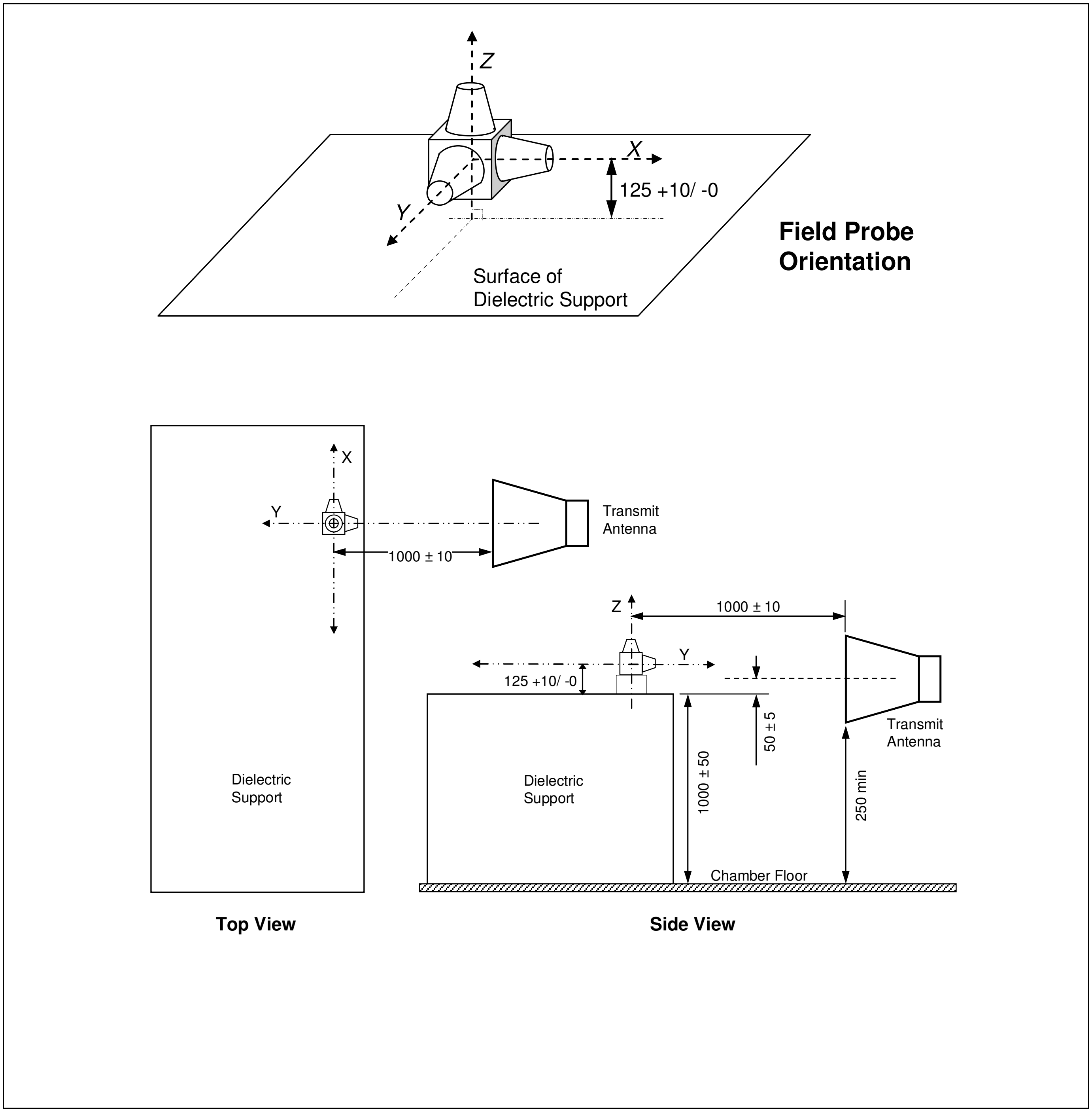
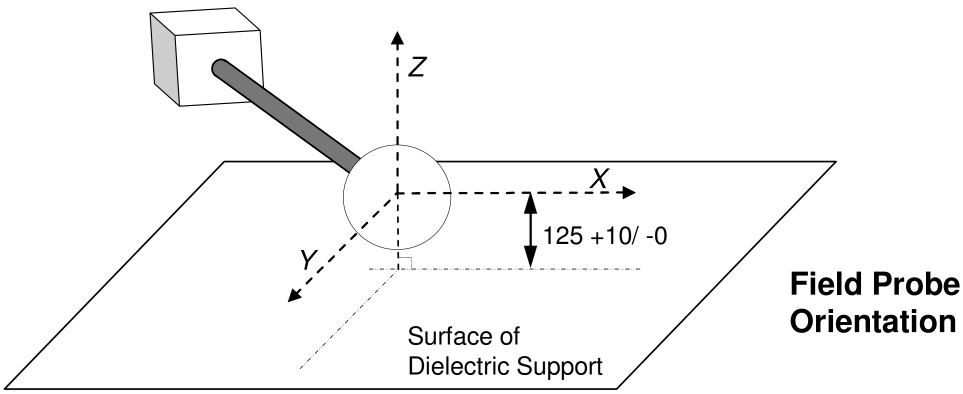


**Figure A-2: Field Probe (Type B) Positioning Requirements (RI 114, Bands 6 and 7)**



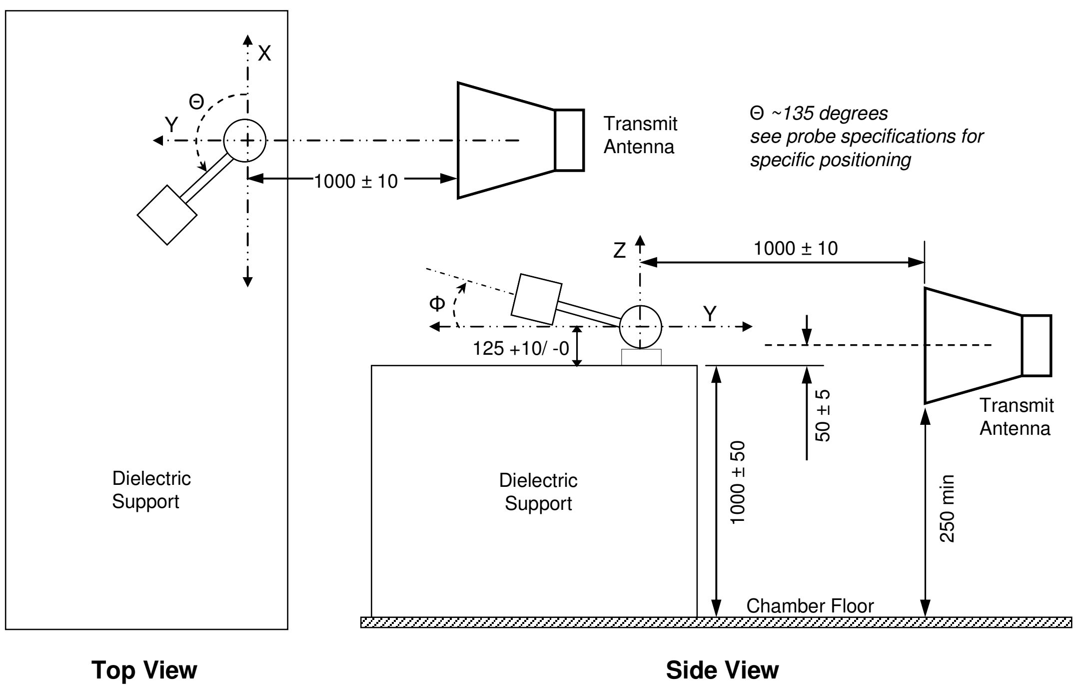
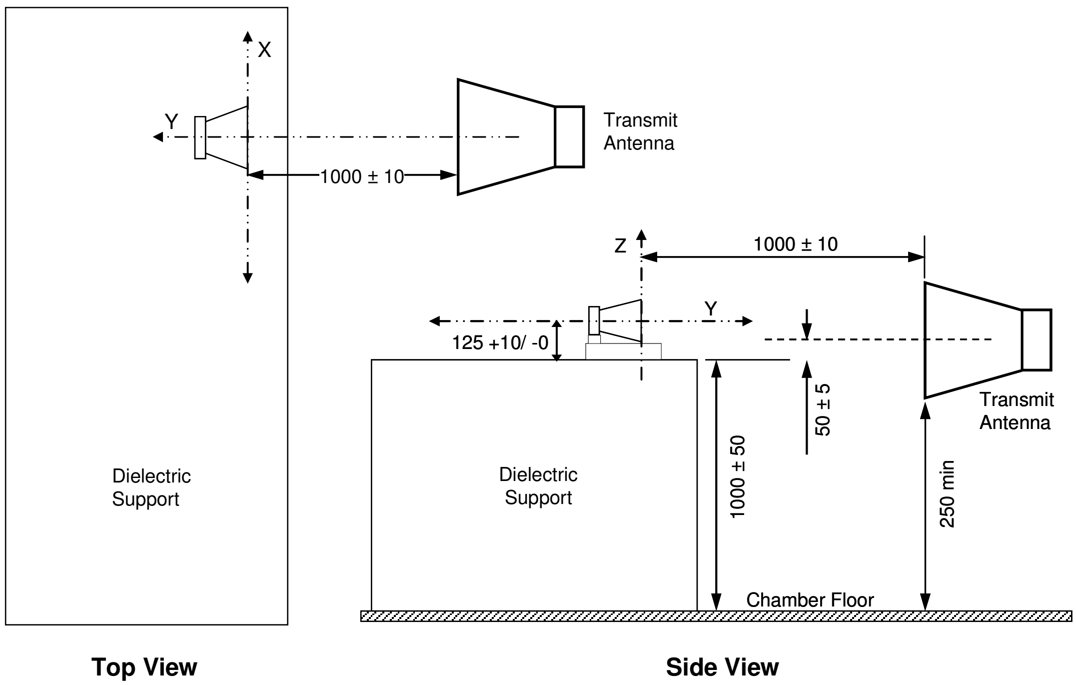



**Figure A-3: Receive Antenna Positioning Requirements (RI 114, Bands 6 and 7)**

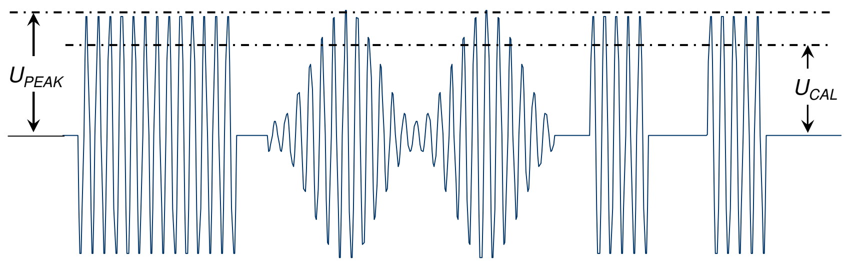


# Annex B (Normative): Modulation & Leveling Requirements for Radiated Immunity

## B.1 Peak Conservation

Peak Conservation, per Annex B of ISO 11452-1 (2005) shall be used for application of AM and Pulse modulation during radiated immunity testing (see section 12). Peak conservation is illustrated in Figure B-1. Peak conservation shall be verified via physical measurement as part of the EMC laboratory's calibration process.

**Figure B-1: RF Immunity Peak Conservation Profile**




$U_{CAL}$ = Stress Level (RMS) listed in Tables 12-1, 12-5, and 12-7

$U_{PEAK}$ = Peak Stress Level

## B.2 Stress Leveling Process

During testing per RI 112, RI 114 and RI 115, there are a minimum of three distinct stages that occur at each test frequency as illustrated in Figure B-2.

Stage 1 consists of the leveling process to achieve the required stress level at each test frequency. Stage 1 is initiated by setting the signal generator output to produce a stress level > 10 dB below the required stress level (i.e. $U_{CAL}$). Signal generator values are derived based on the stress level calibration. The leveling process is critical to assure that the required stress level is not exceeded by more than 1.0 dB. Two factors may affect this

1 <u>Selection of the stress increment "A" (see Figure B2)</u>

The lab may elect to use a small, fixed stress increment value during the leveling process however consideration shall be given toward minimizing the leveling time while not exceeding the target stress level by more than 1 dB. Alternatively, the selected stress increment may variable depending on difference between the measured stress level and the target stress level. The total leveling time should not exceed 6 seconds.

2 <u>RF signal source overshoot during step changes in its output to the RF amplifier.</u>

Overshoot may not exceed 1 dB of the target stress level. A number of hardware and software parameters may be employed to minimize overshoot. The test laboratory should avoid step changes in electromechanical attenuation during the leveling process, which can be a significant source of overshoot. Although not required, use of signal generators with electronic attenuation is recommended.

Depending on the requirement, the leveling process is performed in either CW or Pulse modulation (e.g. RI 115).

Stage 2 occurs when the required stress level has been achieved. The stress level shall remain constant for a minimum dwell time of 2 seconds unless longer times are documented in the DUT's EMC test plan. During this time, CW, AM, or Pulse modulation may be used. The laboratory may perform separate tests for each modulation type or cascade the modulation types at each frequency (recommended). This later approach is illustrated in Figure B-3. If this approach is taken, the laboratory shall take steps to differentiate DUT anomalies attributed to a specific modulation type.

When the dwell time is completed, the required stress level shall be reduced by > 10 dB (Stage 3). At this time, the next test frequency is selected and the process described above is repeated. By default, the time duration of Stage 3 is affected only by the time it takes to move to the next frequency and initiate the leveling procedure (Stage 1). This is hardware and/or test software dependent.

**Figure B-2: RF Immunity Generic Leveling/Dwell Process**

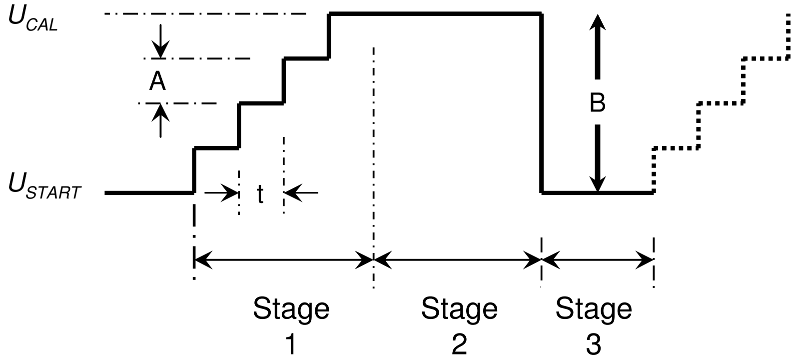
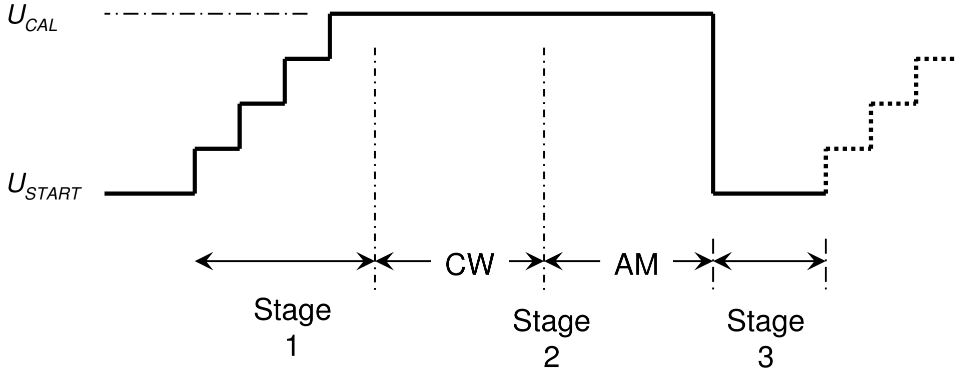



**Figure B-3: RF Immunity Example of Combined CW and AM Dwell**




**Key**

**Stage 1**: Leveling Stage

**Stage 2**: Dwell Stage (default 2 secs)

**Stage 3**: Stress Removed. Switch to next frequency (hardware/ software dependent)

t: time required to measure RF power (hardware\software dependent)

$U_{START}$: Initial Stress Level : >10 dB below $U_{TARGET}$

$U_{TARGET}$: Target Stress Level

A: Stress Increment (may be fixed or variable)

B: Post Dwell Level: > 10 dB below $U_{TARGET}$ of next test frequency

## B.3 DUT Functional Deviation Threshold Procedure

Although RI 112, RI 114 and RI 115 stress levels pertain to current, electric field and net power respectively, forward power is the reference parameter used during calibration in all cases. Through use of this common parameter, determination of a DUT functional deviation (anomaly) threshold level shall be accomplished using the following procedure:

1. Reduced the forward power until the DUT functional deviation disappears,
2. Increase the forward power by steps not exceeding 1 dB, until the functional deviation reappears. Record this level.
3. Subtract the recorded value from step 2 from the forward power recorded during calibration (forward power required to reach the specified stress level). Record this difference in "dB" as the threshold below the required stress level.

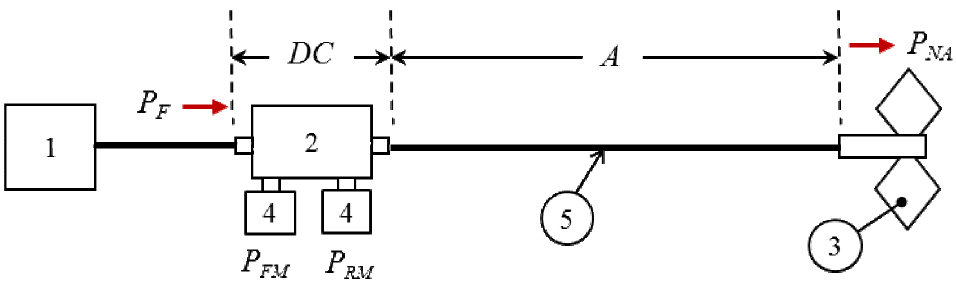
# Annex C (Normative): RI115 Characterization Procedures

The RI 115 characterization procedure facilitates accurate delivery of net power to the transmit antenna per the levels listed in Table 12-7. The net power is derived from the forward power measured at the directional coupler remotely connected to the antenna via low loss coaxial cable. The characterization procedure described herein, is based on ISO 11451-3, but fully considers the effects of mismatch losses that if not controlled will impact the accuracy of the net power.

The reflected power measured at the directional coupler, is not required for determining the net power delivered to the transmit antenna. However, the reflected power must be monitored and recorded during testing to provide feedback regarding the stability of the net power over time. For this reason, this annex includes procedures for parameter characterization required to facilitate measurement of the reflected power during testing.

Figure C-1 illustrates a simplified RI 115 test equipment setup. In this setup, there is a single cable connecting the directional coupler directly to the SBA antenna. Also, the peak wideband power sensors are connected directly to the coupler (i.e. no interconnecting cable).

**Figure C-1: Simplified RI 115 Test Setup**




Key:

1. Signal Source
2. Dual Directional Coupler
3. Transmit Antenna
4. Peak Wideband Power Sensor (e.g. R&S NRP-Z81)
5. Low Loss Coaxial Cable

The relationship between the measured forward and reflected power ($P_{FM}$, $P_{RM}$) and net power ($P_{NA}$) delivered to the antenna is:

$$P_{FM} = \frac{CF_F \cdot P_{NA}}{(A \cdot DC)\cdot(1-\rho^2)} \quad \text{and} \quad P_{RM} = \frac{CF_R \cdot A \cdot \rho^2 \cdot P_{NA}}{(1-\rho^2)}$$

Where:

$P_{NA}$ Net power to the antenna as delineated for Table 12-7

$P_{FM}$ : Measured forward power at the directional coupler

$P_{RM}$ : Measured reflected power at the directional coupler

$\rho$: Magnitude of reflection coefficient of transmit antenna.

$$\rho = \frac{VSWR-1}{VSWR+1}$$

$A$ : Transmission loss of the cable (< 1)

$$A = 10^{\frac{A(dB)}{10}} \qquad A(dB) < 0$$

$DC$: Transmission loss of the directional coupler

$$DC = 10^{\frac{DC(dB)}{10}} \qquad DC(dB) < 0$$

$CF_F$ : Forward coupling factor (< 1)

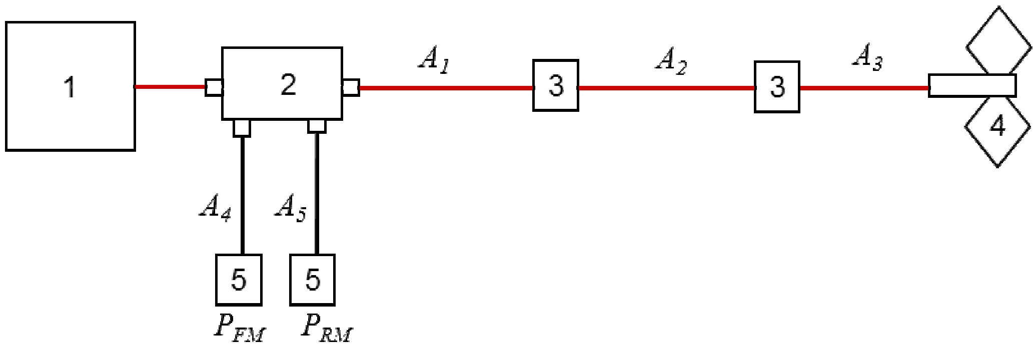
$$CF_F = 10^{\frac{CF_F(dB)}{10}} \qquad CF_F(dB) < 0$$

$CF_R$ : Reflected coupling factor (< 1)

$$CF_R = 10^{\frac{CF_R(dB)}{10}} \qquad CF_R(dB) < 0$$

In most implementations of the RI 115 test equipment setup, other components (e.g. adaptors, bulkhead connectors) are included in the test setup. Figure C-2 illustrates and example of a more complex test equipment setup.

**Figure C-2: Typical RI 115 Test Setup**




Key:

1. Signal Source
2. Directional Coupler
3. Coaxial Connectors/Adaptors
4. Transmit Antenna
5. Peak Power Sensors

$A_1$- $A_{10}$: Interconnecting coaxial cables

For this specific test setup, the relationship between the measured forward and reflected power ($P_{FM}$, $P_{RM}$) and net power ($P_{NA}$) delivered to the antenna is:

$$P_{FM} = \frac{T_2 \cdot P_{NA}}{T_1 \cdot (1-\rho^2)} \quad (1)$$

$$P_{RM} = \frac{T_3 \cdot T_1 \cdot \rho^2 \cdot P_{NA}}{(1-\rho^2)} \quad (2)$$

Where:

$T_1 = A_1 \cdot A_2 \cdot A_3 \cdot DC$: Transmission Loss between coupler output and antenna ($T_1$, $A_1$, $A_2$, $A_3$, $DC < 1$)

$T_2 = A_4 \cdot CF_F$: Transmission Loss between coupler and forward power measurement point ($T_2$, $A_4$, $CF_F < 1$)

$T_3 = A_5 \cdot CF_R$: Transmission Loss between coupler and reflected power measurement point ($T_3$, $A_5$, $CF_R < 1$)

$A_1$, $A_2$, $A_3$, $A_4$, $A_5$: Transmission loss of interconnecting cables

*Note: The characterization procedure delineated in this annex pertains to the general test setup shown in Figure C-2. Alternative test setups using multiple directional couplers, coaxial switches etc, shall be first reviewed by FMC EMC department with an agreed to and documented characterization plan specific to that test setup.*

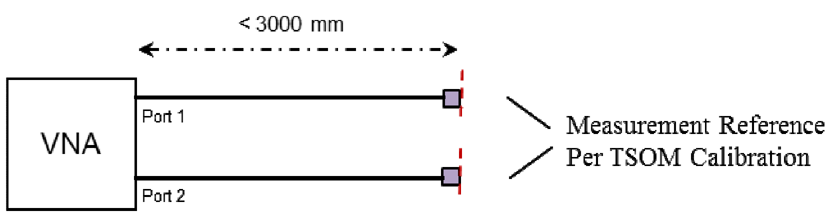
The equations for the measured forward and reflected power often do not include the transmission losses due to the adaptors and coaxial interconnects (e.g. test chamber bulkhead connectors). Also, the equations neglect the effect of mismatch losses which can impact the net power if not controlled. To assure accurate delivery of the net power to the transmit antenna, all transmission and mismatch losses must be managed or accounted for. For this reason, characterization requires:

1) VSWR and transmission loss measurements of the individual components that the test system is comprised of (e.g. cables, directional coupler, coaxial adaptors and interconnects).
2) *"In-situ"* measurements of the VSWR and transmission losses of the assembled test equipment setup.

All measurements shall be performed using a Vector Network Analyzer (VNA) with S-parameter measurement capability. The VNA, when properly calibrated shall be capable of making loss measurements with an accuracy of less than 0.1 dB. The VNA shall be calibrated using the TSOM (Transmission, Short, Open, Match) method via high quality reference (traceable) standards. Cable connections between the VNA and sample shall consist of low loss cables of sufficient length to facilitate connection. Cable length shall not exceed 3000 mm. The cables shall be included in the VNA calibration per Figure C-3. Adaptors should be avoided, but if used, they shall be included in the VNA calibration.

Refer to Figure C-2 for component references for all measurements presented herein

**Figure C-3: VNA TSOM Calibration**




It is important to realize that *S* parameters relate to voltages of an N-port network. VNA measurements of these parameters are often expressed in units of "dB". Example: with respect to $S_{21}$ (i.e. transmission loss), the linear magnitude is expressed as:

$$|S_{21}| = 10^{\frac{S_{21}(db)}{20}}$$ Where $S_{21}$ *(dB)* is the measured value by the VNA

However, transmission loss, as expressed via $T_1$, $T_2$, $T_3$ in equations 1) and 2) is in terms of power. If $S_{21}$ is measured in units of db, the relationship between it and the transmission loss (e.g. $T_1$) is:

$$T_N = 10^{\frac{S_{21}(db)}{10}} \qquad (3)$$

To avoid confusion, all references to measurement of $S_{21}$ are assumed to be in units of dB within this annex

## C.1 Directional Coupler Parameter Verification

The directional coupler used in the RI 115 test setup shall be characterized using the following procedures.

### C.1.1 VSWR and Transmission Loss Measurement Procedure

1) Connect the VNA to the directional coupler as illustrated in Figure C-4. Connect 50 ohm terminations to the P3 and P4. The termination shall have a VSWR less than 1.3 over the RI 115 frequency range.

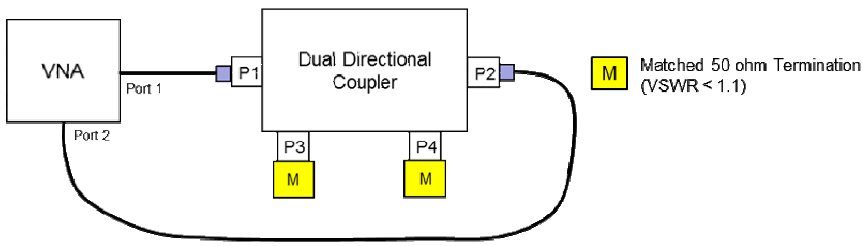
2) Measure and record the magnitude of $S_{11}$ and $S_{22}$ of P1 and P2 over the RI 115 frequency range. Calculate and verify the VSWR at P1 and P2 is less than 1.3.

Where: $VSWR_{P1} = \frac{1+|S_{11}|}{1-|S_{11}|}$ and $VSWR_{P2} = \frac{1+|S_{22}|}{1-|S_{22}|}$ $(|S_{11}| \text{ and } |S_{22}| < 1)$

3) Measure and record the magnitude of $S_{21}$. Calculate/record the insertion loss $DC$. Verify $DC$ is less than 0.5 dB over the RI 115 frequency range.

Where: $DC = 20 \cdot Log|S_{21}|$ $(|S_{21}| < 1)$

**Figure C-4: P1, P2 VSWR and Insertion Loss Verificaiton**




### C.1.2 VSWR and Forward Coupling Factor Measurement

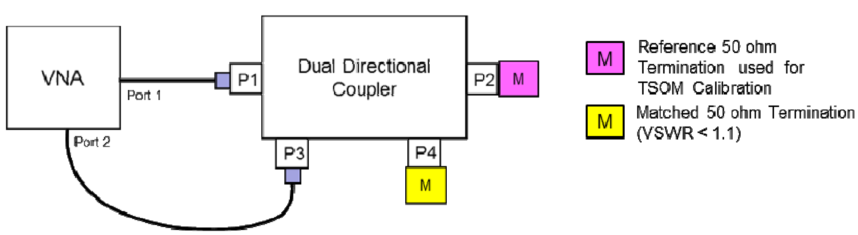
1) Connect the VNA to the directional coupler as illustrated in Figure C-5. Connect a reference matched 50 ohm termination (used for VNA calibration) to P2. Connect a 50 ohm termination (VSWR < 1.3) to P4.

2) Measure and record the magnitude of $S_{22}$ of P3 over the RI 115 frequency range. Calculate and verify the VSWR at each connector is less than 1.5.

3) Measure and record the magnitude of $S_{21}$. Calculate/record forward coupling factor, $CF_F$ over the RI 115 frequency range. Verify $CF_F$ is greater than 20 dB.

Where: $CF_F(dB) = 20 \cdot Log|S_{21}|$ $(|S_{21}| < 1)$

**Figure C-5: Setup for Forward Coupling Factor ($CF_F$) and P3 VSWR Verificaiton**



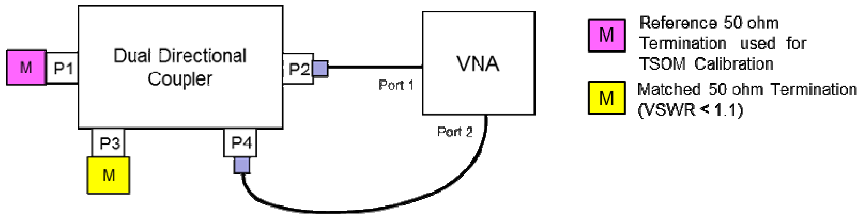

### C.1.3 VSWR and Reflected Coupling Factor Measurement

1) Connect the VNA to the directional coupler as illustrated in Figure C-6. Connect a reference matched 50 ohm termination (used for VNA calibration) to P1. Connect 50 ohm terminations (VSWR < 1.3) to P3.

2) Measure and record $S_{22}$ of P4 over the RI 115 frequency range. Calculate and verify the VSWR at each connector is less than 1.5.

3) Measure and record $S_{21.}$ Calculate/record $CF_R$ over the RI 115 frequency range. Verify the reflected coupling factor is greater than 20 dB.

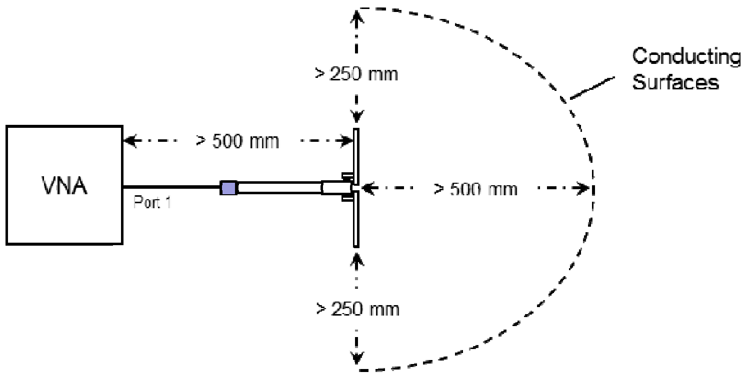
**Figure C-6: Setup for Reflected Coupling Factor ($CF_R$) and P4 VSWR Verification**




## C.2 SBA Antenna Reflection Coefficient Measurement

Connected the VNA to the SBA antenna as shown in Figure C-7. The antenna shall be positioned so that it is separated from the VNA and conducting surfaces as shown in Figure C-7. Measure and record $\rho$ *(i.e. magnitude of* $S_{11}$) of antenna over at all of the test frequencies listed for RI 115.

**Figure C-7: Measurement of $\rho$ of Transmit Antenna**

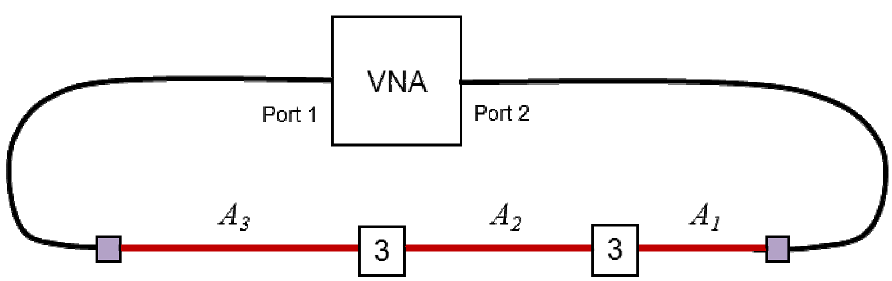



## C.3 Characterization of VSWR of the Antenna Interconnect

Characterization requires *in-situ* measurement of the VSWR for the interconnection between the directional coupler and antenna.

1) Connect the VNA to the antenna interconnect cable assembly as illustrated in Figure C-8.
2) Measure and record the magnitude of $S_{11}$ and $S_{22}$ over the RI 115 frequency range. Calculate and verify the VSWR at each connector is less than 1.1.

**Figure C-8: Measurement of VSWR for Coupler/Antenna Interconnect**




*See Figure C-2 for component references*

*Note:*

*The interconnection between the directional coupler and transmit antenna should ideally have no intermediate connections including cable interconnects, adaptors, coaxial switches etc. Presence of these additional items can increase the VSWR of the interconnection which introduces uncertainty to the net power delivered to the transmit antenna.*

## C.4 Characterization of Transmission Loss for the Coupler /Antenna Interconnect

Characterization requires *in-situ* measurement of the transmission loss for the combination of the directional coupler and antenna interconnect cable.

1) Attach the directional coupler to the interconnect cable assembly. Connect the VNA as illustrated in Figure C-9. The other ports of the coupler shall be terminated with a 50 ohm load with a VSWR less than 1.3.

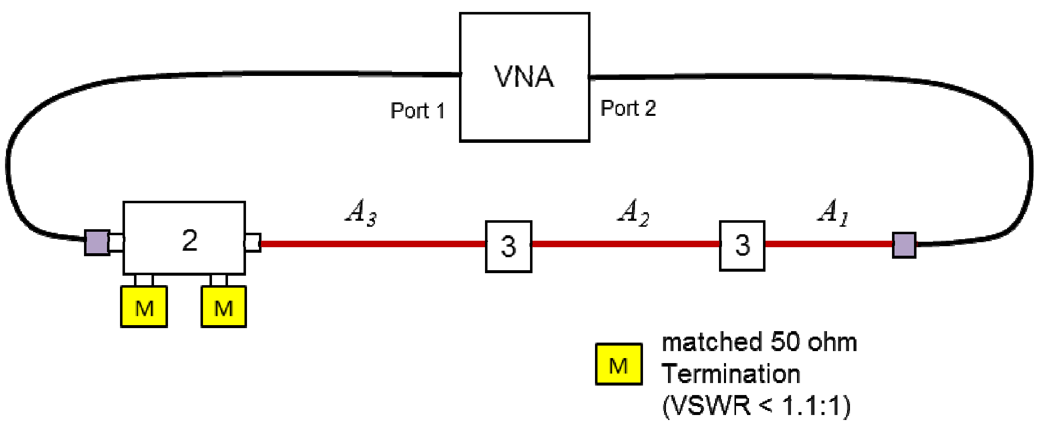
2) Measure the magnitude of $S_{21}$. Record the transmission loss $T_1$ using:

$$T_1 = |S_{21}|$$

3) Verify that $T_1$ is less than 4 dB:

Where: $T_1(dB) = 20 \cdot Log|S_{21}|$

**Figure C-9: Measurement of $T_1$**

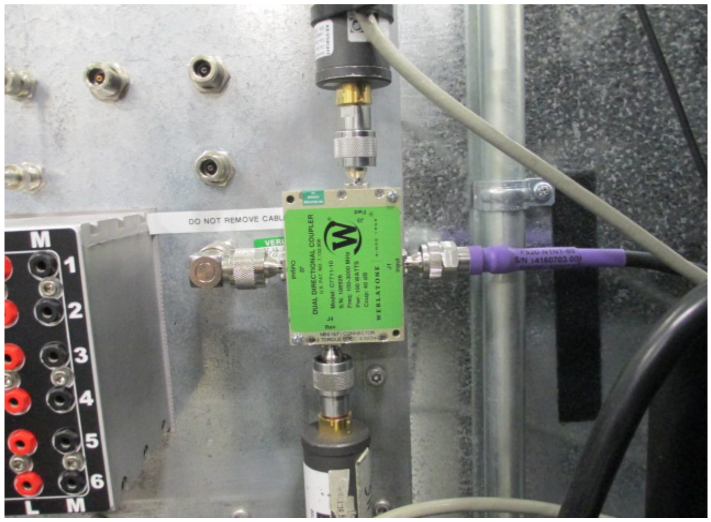


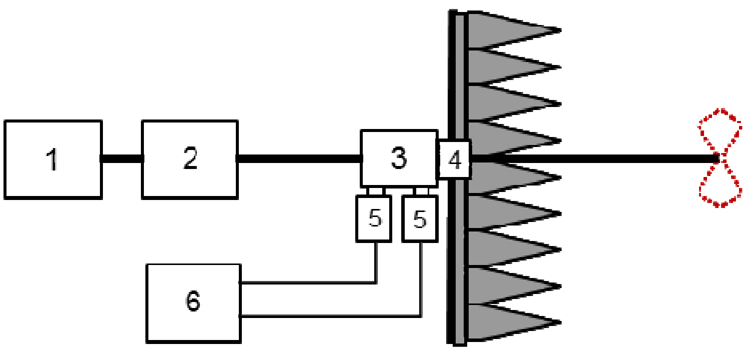

*See Figure C-2 for component references*

*Note:*

*It is highly recommended to use a single directional coupler to cover the entire frequency band of RI 115. The coupler should be attached directly to the bulkhead connector at the ALSE shield boundary. This arrangement is illustrated in Figure C-10. If multiple couplers are used, use of coaxial switches to facilitate interface to the connecting cable, must be included with the interconnecting cable assembly for in-situ measurement of the VSWR per section C.3.*

**Figure C-10: Recommended Directional Coupler Placement**






Key:

1. Signal Generator
2. RF/uW Amplifier
3. Directional Coupler
4. Bulkhead Coaxial Connector (Type N recommended)
5. Peak Power Sensors
6. Power Meter

## C.5 Characterization of VSWR and Transmission Loss for the Coupler/Power Sensor Interconnect

Connect all of the elements that comprise the directional coupler and interconnect between it and connection point of the power sensors. Characterization requires *in-situ* measurements of the VSWR and transmission loss of the interconnections between the directional coupler and power sensors. Figure C-2 is used as a reference to provide guidance of how to carry out these *in-situ* measurements for laboratory specific equipment test setups. Alternative methods (e.g. separate component measurements) are not permitted.

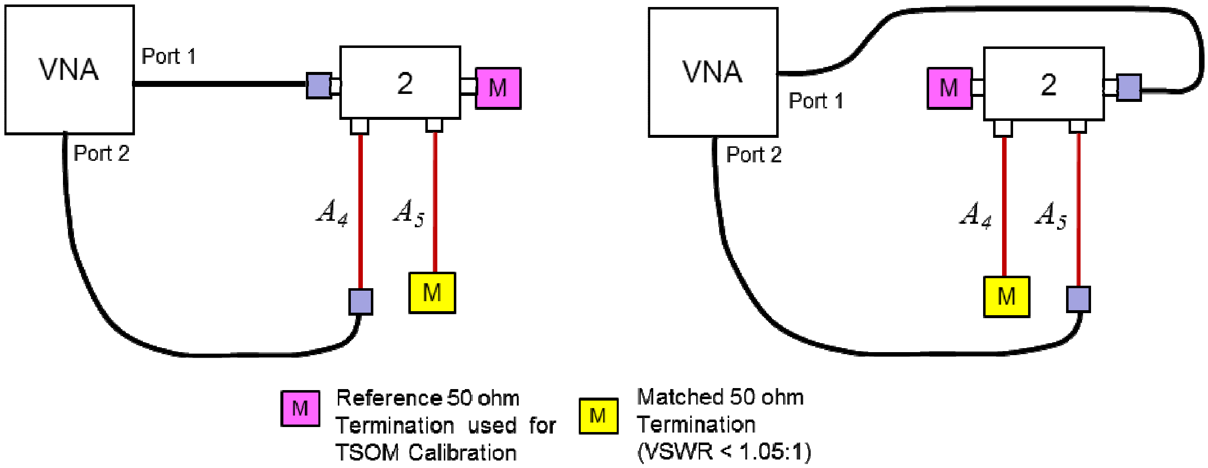
1) Connect the VNA to the directional coupler input and the forward power measurement point as illustrated in Figure C-10a. Connect a reference "matched" termination on the output of the coupler. The reflected power measurement point shall be terminated with a 50 ohm load with a VSWR less than 1.3

   Measure and record the magnitude of $S_{11}$ and $S_{22}$ of the respective connections over the RI 115 frequency range. Calculate and verify the VSWR at each connector is less than 1.3.

2) With the VNA remained connected as illustrated in Figure C-10a, Measure the magnitude of $S_{21}$. Record the transmission loss $T_2$ using:

$$T_2 = |S_{21}|$$

**Figure C-10: Measurement of $T_2$ and $T_3$**




**(a)** **(b)**

3) Connect the VNA to the directional coupler output and the reflected power measurement point as illustrated in Figure C-9b. Connect a reference "matched" termination on the input of the coupler. The forward power measurement point shall be terminated with a 50 ohm load with a VSWR less than 1.3. Measure and record the magnitude of $S_{11}$ and $S_{22}$ of the respective connections over the RI 115 frequency range. Calculate and verify the VSWR at each connector is less than 1.3.

4) With the VNA remained connected as illustrated in Figure C-9a, Measure the magnitude of $S_{21}$. Record the transmission loss $T_3$ using:

$$T_3 = |S_{21}|$$

# Annex D (Normative): CI 220, CI 221, C222 Transient Waveform Descriptions

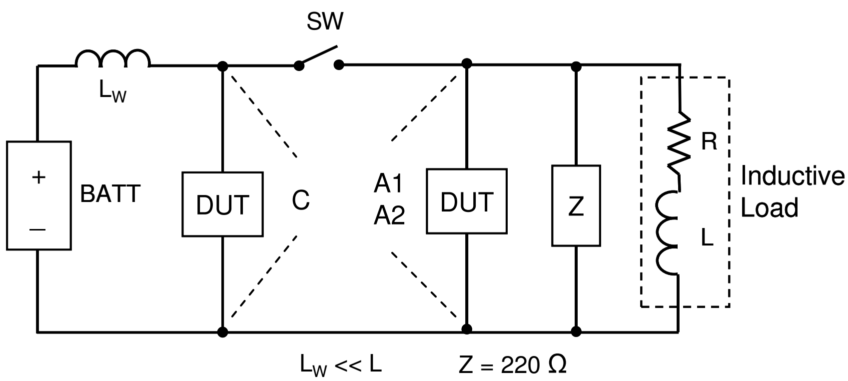
CI220 transient immunity testing consists of both standard pulses as delineated in ISO 7637-2 in addition to non-standard pulses including those produced by electromechanical switching of an inductive load. These non-standard transient pulses have been included to produce transient waveforms that are absent in ISO 7637-2, but are prevalent in the vehicle's electrical power distribution system. Non-standard transients created from this approach are highly affected by a number of factors including but not limited to resistive/capacitive loads sharing the same circuit as the inductive load. Although consecutive transients events produced in this manner are often not repeatable as compared to standard ISO test pulses, experience has shown that this random behavior can produce anomalies that are frequently missed when using only the standard repetitive ISO pulses.

This annex provides information about the characteristics of the CI 220 transient pulses delineated in this specification. This information shall also be considered during initial design of the component or subsystem.

## D.1 Test Pulses A1, A2, C

Figure D-1 illustrates a simplified automotive circuit consisting of a switch used to activate or deactivate the inductive load (e.g. power door lock). $L_W$ represents the series wiring inductance between the battery, and ignition switch. The load inductance "L" is significantly greater than the series inductance of the wiring (typically 1 uH/meter).

**Figure D-1: Simplified Automotive Circuit for Transient Immunity**




**Test Pulse A1** represents the voltage transient produced during switching of higher current (1 – 5 ampere) inductive loads that share the same circuit with the DUT. "Z" represents the impedance of the other electrical loads sharing the same circuit with the DUT and the inductive load. The value of "Z", which is set to 220 Ω, simulates minimally loaded circuits. Figure D-2 illustrates Pulse A1. The peak pulse voltage levels will vary between –250 to –300 volts.

**Test Pulse A2** represents the voltage transient produced during switching of a lower current (< 1 ampere) inductive loads that shares the same circuit with the DUT. The characteristics of Pulse A2 can vary significantly depending on the impedance of the other loads sharing the same circuit as the DUT. Given this dependency, two separated conditions exist for Pulse A2. They are:

<u>Pulse A2-1</u>

Occurs when the circuit consists only of the DUT and the switched inductive load.

<u>Pulse A2-2</u>

Occurs when the circuit includes other electrical loads that share the same circuit as the DUT and the switched inductive load.. The other electrical loads are predominately capacitive (e.g. wiper motor filter capacitor)

Figures D-3 and D-4 illustrate waveforms that typify Pulses A2-1 and A2-2. When external circuits effects are not considered, the transient (Pulse A2-1) is largely the result of contact arcing. The characteristics of this transient consist of a high frequency repetitive pulse with peak positive voltages levels between +100 to +300 volts and peak negative voltage levels are between –280 to –500 volts. Duration of individual pulses (see Figure D-3b) may vary between 100 nsec to 1 usec. The characteristics illustrated in Figure D-3 were measured when the contacts open, however similar transients can occur when the switch contact bounce during closure. A2-1 transients are also commonly referred to as "showering arc transients."

When the external circuit is predominately capacitive, the transient produced (Pulse A2-2) is significantly different than Pulse A2-1. When the switch contacts open, a damped sinusoidal transient ($f_{res}$ ~ 2kHz) is produced. When the switch contacts bounce during closure a higher frequency, damped sinusoidal transient ($f_{res}$ ~180kHz) is produced. During this phase, there is a corresponding current transient with a magnitude approximately 30 $A_{P-P}$ (see Figure D-4c). *When attempting to measure Pulse A2-2, on an oscilloscope, it is recommended to trigger on the transient current.*

**Figure D-2: Pulse A1 Composite Waveform**

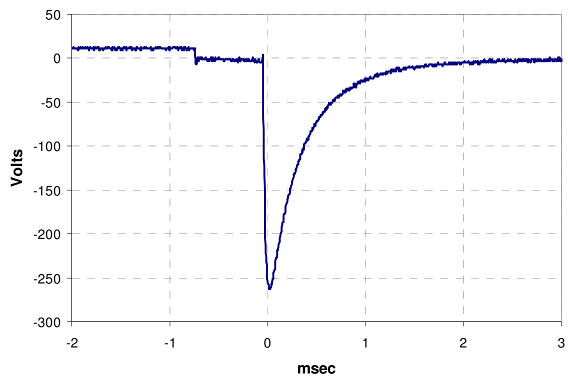
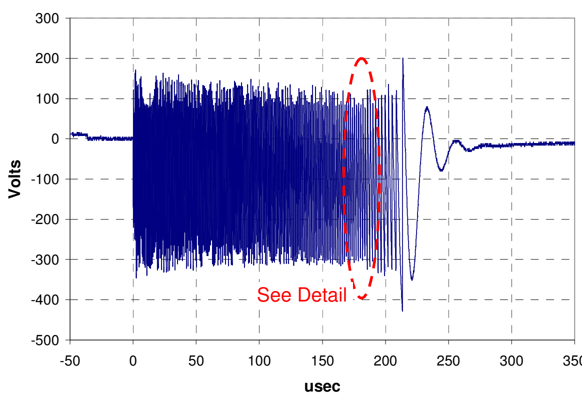
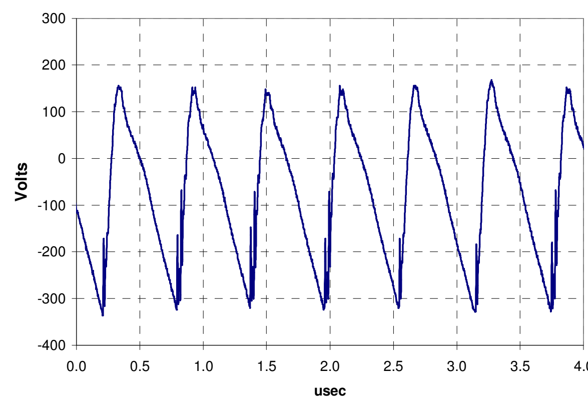



**Figure D-3: Pulse A2-1 Pulse Characteristics**

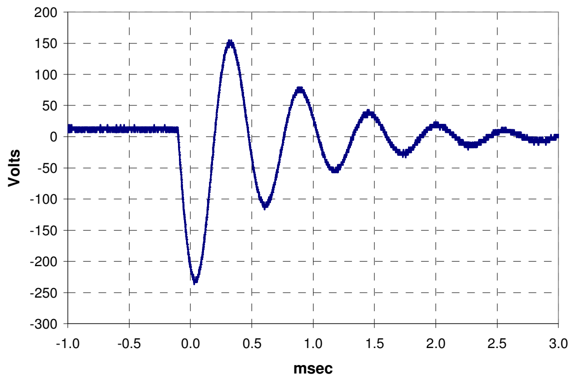



a) Contact Break and Bounce

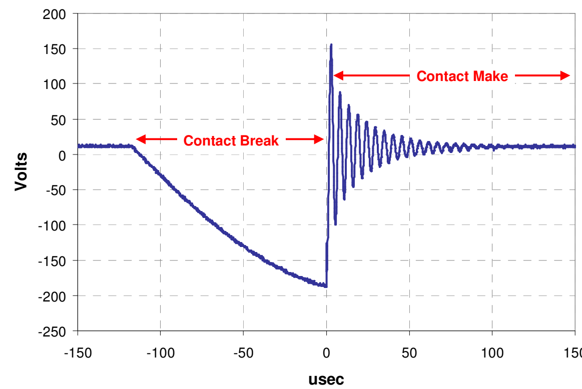



b) Contact Break and Bounce (Detail)

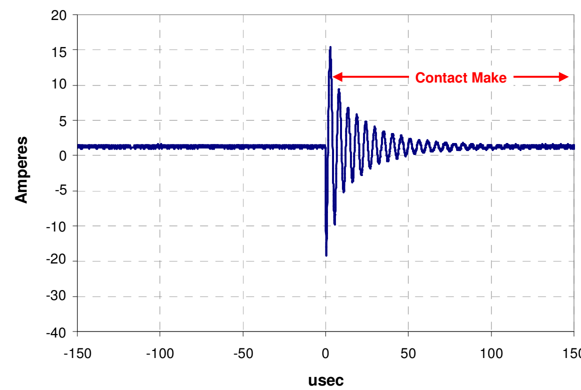
**Figure D-4: Pulse A2-2 Pulse Characteristics**




a) Contact Break




b) Contact Bounce (Voltage)




c) Contact Bounce (Current)

**Test Pulse C** represents the voltage transient produced as a result of switch contact arching and contact bounce during switching of an inductive load. The transient characteristics are a function of the series wiring inductance and the current produced during arcing (switch contact break) or contact bounce. Pulse C is directly related to Pulse A2. Given this dependency, two separated conditions exist (Pulse C-1, C-2) corresponding to Pulses A2-1 and A2-2 respectively.

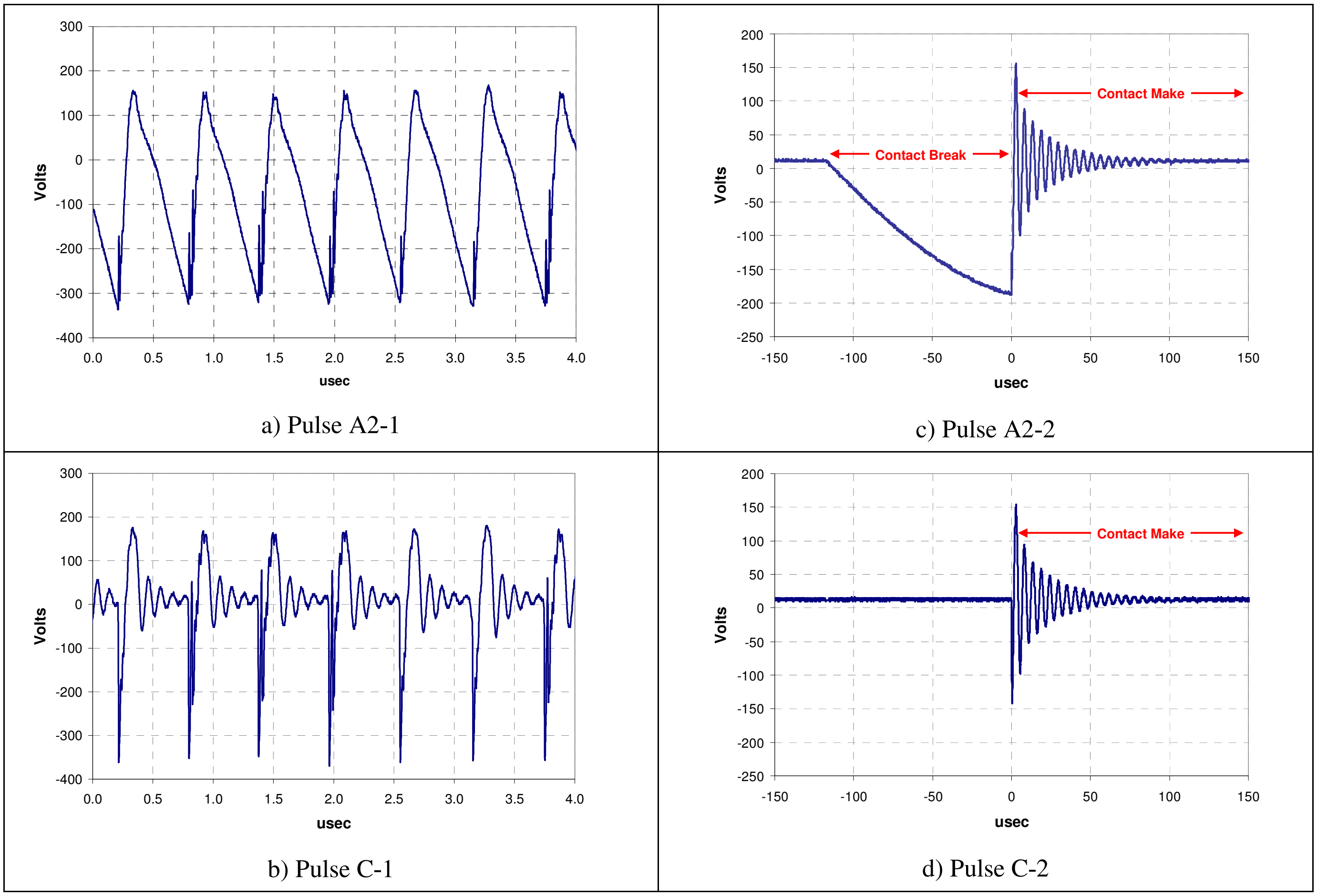
Pulse C-1

The characteristics of this transient consist of a high frequency damped sinusoidal pulse ($f_{res}$ ~ 10 MHz) with the peak positive voltages levels between +150 to +250 volts and peak negative voltage levels are between –280 to –400 volts. Pulse C-1 characteristics are illustrated in D-5b.

Pulse C-2

The characteristics of this transient consist of a lower frequency damped sinusoidal pulse ($f_{res}$ ~ 180 kHz) with peak positive and negative voltages levels approximately ±150 volts. Duration of the sinusoidal transient pulse is approximately 50 usec. Pulse C-2 characteristics are illustrated in D-5d.

**Figure D-5: Pulse C Characteristics**




a) Pulse A2-1 c) Pulse A2-2

b) Pulse C-1 d) Pulse C-2

## D.2 ISO Pulses 1 , 2 and 3

**Pulse 1** represents the voltage transient produced during switching of a higher current (> 5 ampere) inductive load that shares the same circuit with the DUT. Pulse 1 is similar to Pulse A-1 except that it occurs when higher current loads (> 5 amperes) share the same circuit as the inductive load. The pulse can also occur on circuits with high capacitive loads (> 2uf). Pulse 1 characteristics are illustrated in Figure D-6.

**Pulse 2a** simulates the interruption of a current through an inductance switched in series with the DUT. Pulse 2a characteristics are illustrated in Figure D-7.

**Pulse 2b** simulates the interruption in current to brush commutated motor, which is low-side switched. Pulse 2b characteristics are illustrated in Figure D-8.

**Pulses 3a and 3b** represents the voltage transient which is the result of switch contact arching and contact bounce during switching of an inductive load. The transient pulses are simplistic representations of Pulse C. Pulse 3a and 3b characteristics are illustrated in Figures D-9 and D-10.

**Figure D-6: ISO Pulse 1 Characteristics**

Pulse 1 – Parameters

| | | |
|---|---|---|
| $U_A$ | 13.5 VDC | 27 VDC |
| $U_s$ | See Tables 17-1 and 18-1 | |
| $R_i$ | 10 Ω | 50 Ω |
| $t_d$ | 2 ms | 1 ms |
| $t_r$ | 1 (+0/ -0.5) us | 3 (+0/-1.5) us |
| $t_1$ | 0.5 s (≥ 30 s)[1] | |
| $t_2$ | 200 ms | |
| $t_3$ | ≤ 100 us | |

(1) See Table 17-1.

Waveform voltage begins and ends at $U_A$

Parameters listed are for open circuit conditions.

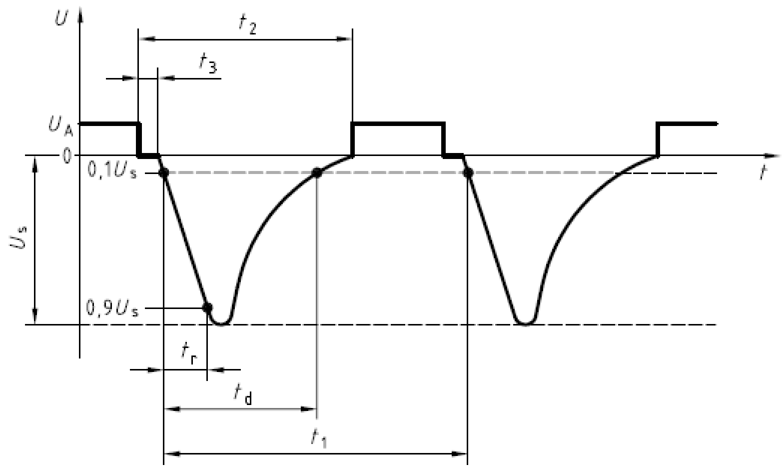



**Figure D-7: ISO Pulse 2a Characteristics**

Pulse 2a - Parameters

| | | |
|---|---|---|
| $U_A$ | 13.5 VDC | 27 VDC |
| $U_s$ | See Table 18-1 | |
| $R_i$ | 2 Ω | |
| $t_d$ | 0.05ms | |
| $t_r$ | 1 (+0/-0.5) us | |
| $t_1$ | 0.2 s | |

Waveform voltage begins and ends at $U_A$

Parameters listed are for open circuit conditions.

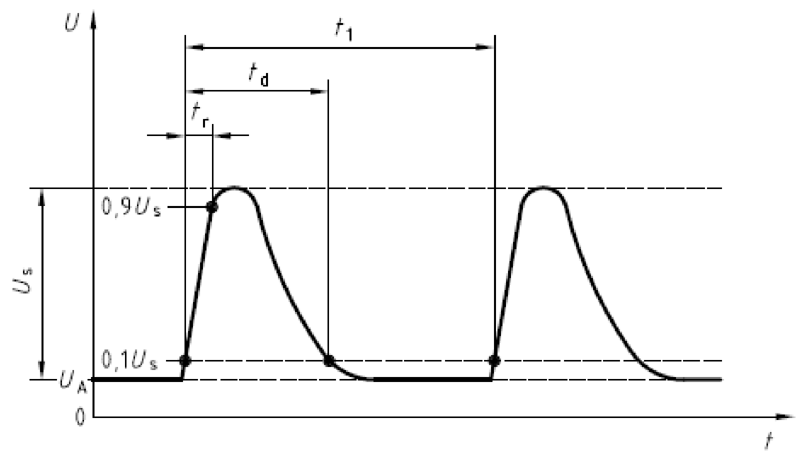



**Figure D-8: CI 220 Pulse 2b Pulse Characteristics**

Pulse 2b - Parameters

| | | |
|---|---|---|
| $U_A$ | 13.5 VDC | 27 VDC |
| $U_s$ | See Table 18-1 | |
| $R_i$ | < 0.05 Ω | |
| $t_d$ | 0.2 – 2 s | |
| $t_{12}$ | 1 ( ± 0.5) ms | |
| $t_r$ | 1ms (± 0.5) ms | |
| $t_6$ | 1ms (± 0.5) ms | |

Parameters listed are for open circuit conditions.

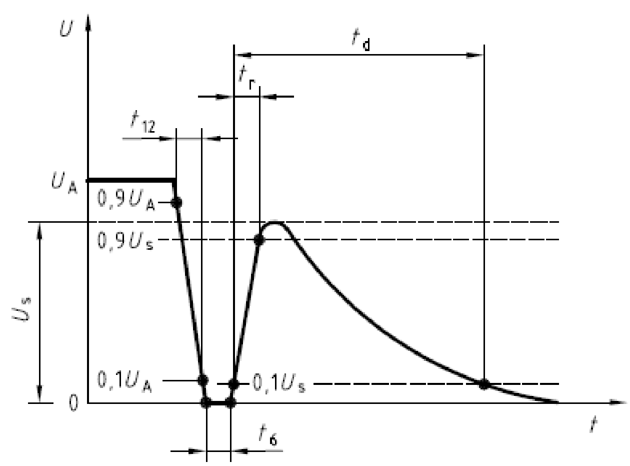


**Figure D-9: ISO Pulse 3a Pulse Characteristics**

Pulse 3a - Parameters

| | | |
|---|---|---|
| $U_A$ | 13.5 VDC | 27 VDC |
| $U_s$ | See Table 18-1 | |
| $R_i$ | 50 Ω | |
| $t_d$ | 150 (± 45) ns | |
| $t_r$ | 5 (± 1.5) ns | |
| $t_1$ | 100 us | |
| $t_4$ | 10 ms | |
| $t_5$ | 90 ms | |

Parameters listed are for open circuit conditions.

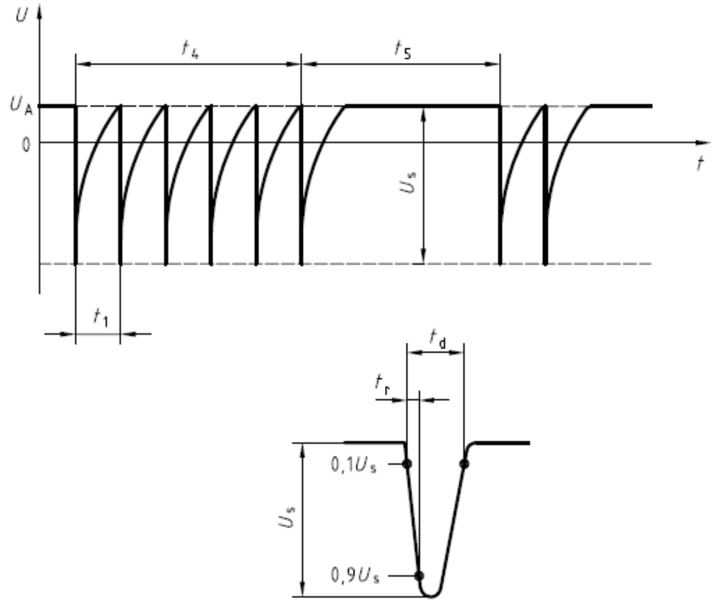
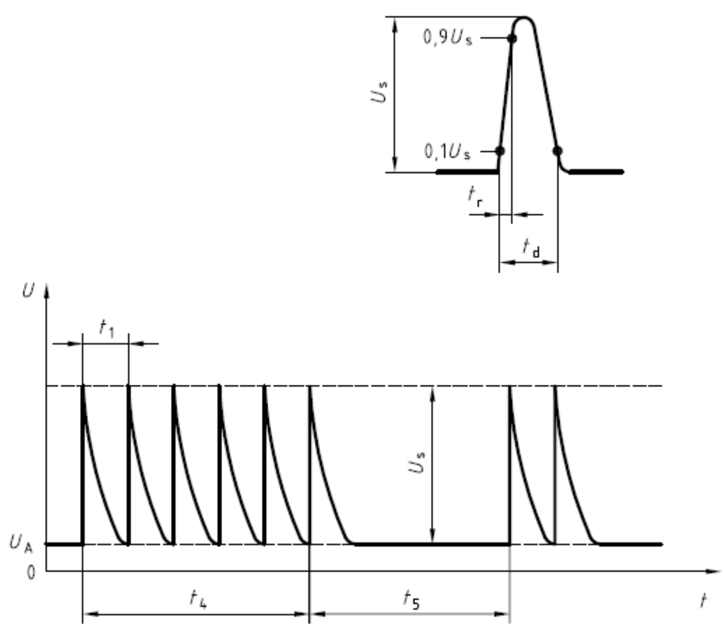



**Figure D-10: ISO Pulse 3b Pulse Characteristics**

Pulse 3b - Parameters

| | | |
|---|---|---|
| $U_A$ | 13.5 VDC | 27 VDC |
| $U_s$ | See Table 18-1 | |
| $R_i$ | 50 Ω | |
| $t_d$ | 150 (± 45) ns | |
| $t_r$ | 5 (± 1.5) ns | |
| $t_1$ | 100 us | |
| $t_4$ | 10 ms | |
| $t_5$ | 90 ms | |

Parameters listed are for open circuit conditions.



## D.3 ISO Pulses 5a and 5b

**Pulse 5a** represents the transient produced due to sudden disconnection of the battery from the alternator (i.e. Load Dump). Pulse 5a characteristics are illustrated in Figure D-11. The pulse amplitude $U_S$ is shown for open circuit and matched load conditions (i.e. $R_L = R_i$ )

**Pulse 5b** represents a voltage clamped transient produced due to sudden disconnection of the battery from an alternator fitted with Central Load Dump Protection. Pulse 5b characteristics are illustrated in Figure D-12.

**Figure D-11: ISO Pulse 5a Characteristics**

Pulse 5a – Parameters[(1)]

| Open Circuit Conditions ($R_L$ = open) | | |
|---|---|---|
| $U_A$ | 13.5 VDC | 27 VDC |
| $U_s$ | See Table 19-1 | |
| $R_i$ | 0.5 Ω | 1 Ω |
| $t_d$ | 300 ms +/-20% | |
| $t_r$ | 10 ms -5 /+0 ms | |

| Loaded Conditions ( $R_L = R_i$) | | |
|---|---|---|
| $U_A$ | 13.5 VDC | 27 VDC |
| $U_s$ | 0.5*$U_S$ (Open Circuit) | |
| $R_i$ | 0.5 Ω | 1 Ω |
| $t_d$ | 150 mS +/-20% | |
| $t_r$ | 10 ( -5 /+0) ms | |

(1) All voltage values are with respect to 0 volts unless otherwise specified.

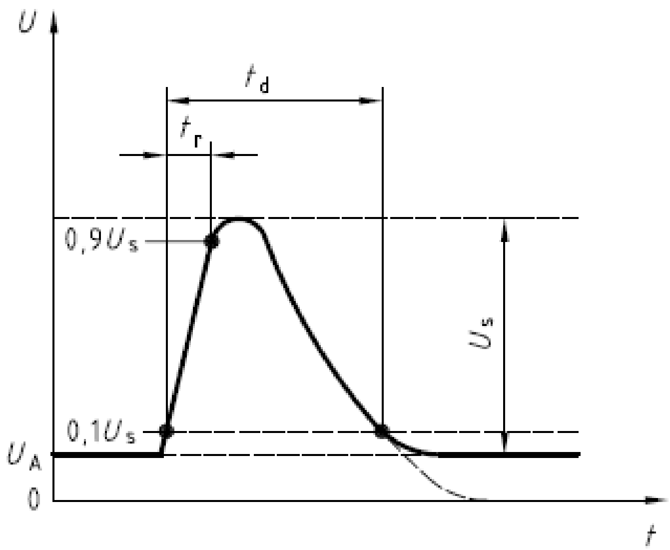



**Figure D-12: ISO Pulse 5b Characteristics**

Pulse 5b Parameters [(1)]

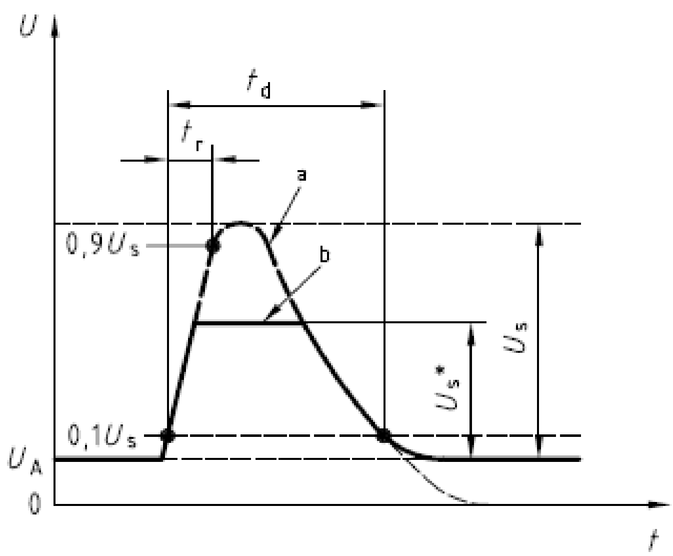
| | |
|---|---|
| $U_A$ | See Table 19-1. |
| $U_s$ (2) | |
| $U_s^*$ (2) | |
| $R_i$ | 0.5 Ohms |
| $t_r$ | 10 ( -5 /+0 ) ms |
| $t_d$ | 150 mS +/-20% |

(1) All voltage values are with respect to 0 volts unless otherwise specified.

(2) $U_S$ and $U_S^*$ based on 0.5 ohm resistive load ($R_L = R_i$).

a: Unsuppressed pulse

b: Suppressed pulse








October 07, 2016

## D.4 Transient Application Mode (Pulses A1, A2 and C)

Application of transient pulses A1, A2 and C to the DUT are facilitated using three different operating modes.

Mode 1 represents a condition where the test pulse is applied at a fixed repetition rate as shown in Table D-1 below. Mode 1 is applicable for pulses A1 and A2 only when applied to any DUT power supply circuit.

**Table D-1: CI 220 Mode 1 Characteristics**

| Transient Pulse | Pulse Repetition Rate (PRR) | Duration |
|---|---|---|
| A1 | 0.2 Hz,<br>10% duty cycle | 120 sec |
| A2-1 | | |
| A2-2 | | |

When the application of Mode 1 is complete, the transient generator output shall return to $U_A$ (13.5 volts) within 200 msec to verify Status II performance.

Mode 2 represents a condition where test pulses are applied using a pseudo-random timing sequence as illustrated in Figure D-13. Mode 2 is only used with test pulse A1 when applied to DUT inputs. The time "T" is 50 ms. When performing CI 220 testing, when the application of Mode 2 is complete, the transient generator output shall return to $U_A$ (13.5 volts) within 200 msec to verify Status II performance.

Mode 3 represents a condition where test pulses are applied using pseudo-random bursts as illustrated Figure D-14. The timing sequence is identical to that used for Mode 2. Mode 3 is used only with test pulses A2-1, A2-2, C-1, and C-2. The bust time "T" is 50ms. When performing CI 220 testing, when the application of Mode 2 is complete, the transient generator output shall return to $U_A$ (13.5 volts) within 200 msec to verify Status II performance.

Modes 2 and 3 is also used when performing testing per RI 130 (see section 14). Modes 1, 2 and 3 are produced by the transient generator circuit presented in Annex E.

**Figure D-13: CI 220 Mode 2 Characteristics**

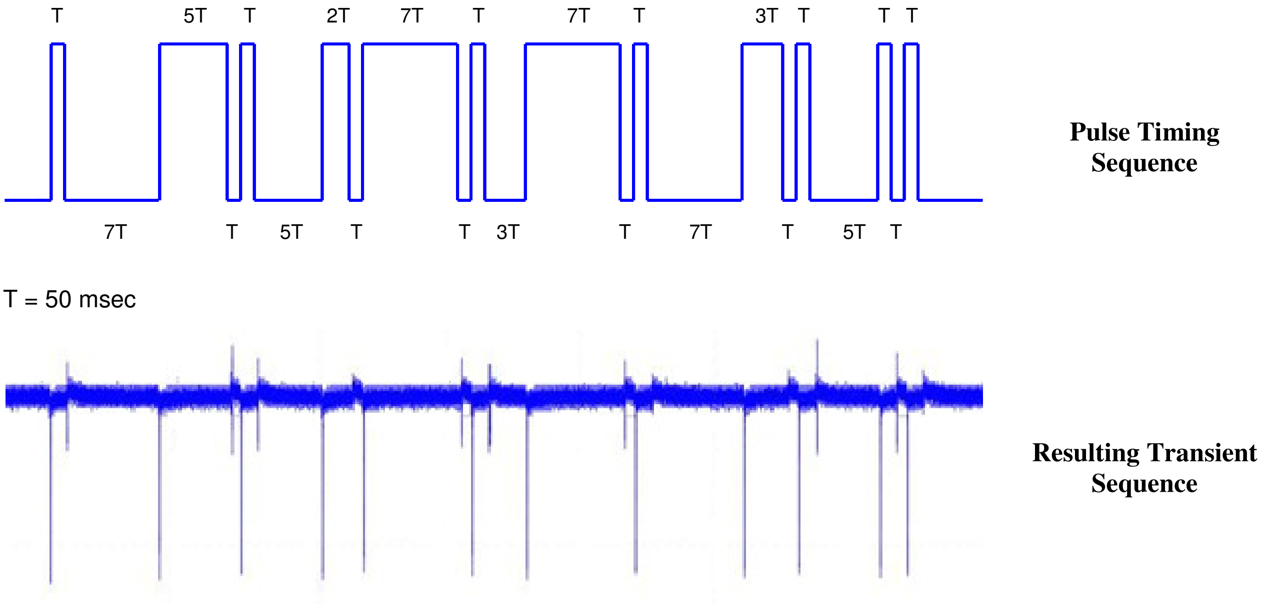
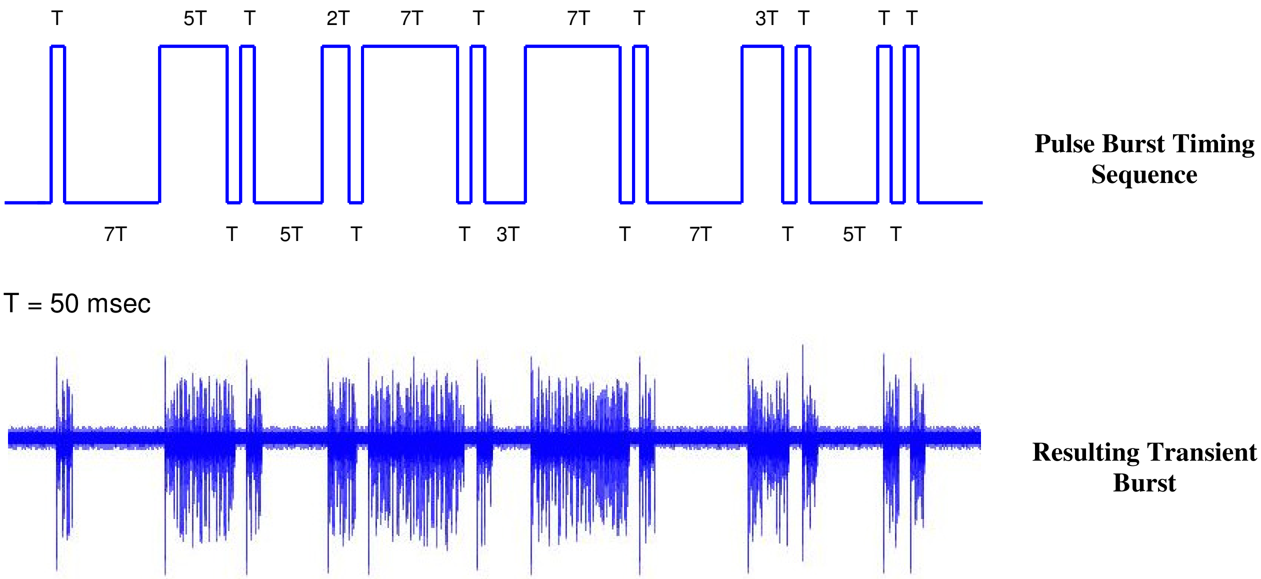



**Figure D-14: CI 220 Mode 3 Characteristics**



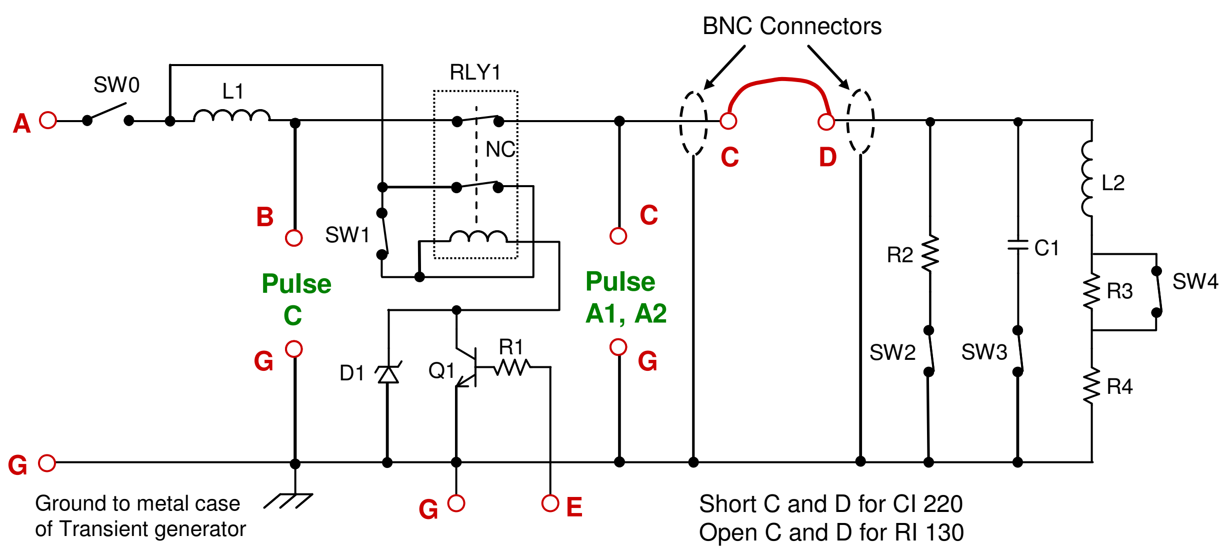
# Annex E (Normative): Transient Test Generator (Pulses A1, A2 and C)

The test generator presented in this annex produces transients for the following test methods:

- RI 130
- CI 220 Pulses A1, A2, and C

Figure E-1 illustrates the transient generator circuit that will produce CI 220 transient pulses A1, A2, and C in Modes 1, 2 and 3. The circuit contains a few critical components that may not be substituted without permission from the FMC EMC department. These components are highlighted in the figures. Specific details about these test circuits including contact locations for critical components may be found at http://fordemc.com. Selection of test pulses and operating modes is facilitated by simple switch settings. Table F-1 summarizes these switch configurations and associated test pulse/operating mode.

**Figure E-1: Transient Generator Circuit for RI 130 and CI 220**




**Key**

| | |
|---|---|
| R1: 51 ohms, 0.25W | L2: 100 mH inductor<br>*(Osborne Transformer Part Number 32416)** |
| R2: 220 ohms ± 5% , 2W | D1: Zener Diode, 39 V, 5W (*1N5366A*) |
| R3: 33 ohms ± 5% , 10W | Q1: NPN transistor (*TIP 41*) |
| R4: 6 ohms ± 5% , 50W | SW0 – SW4: Single Throw Switch (10 contact rating) |
| C1: 100 nF PETP polyester film capacitor, 400V (e.g. VISHAY Type 225 Orange Drop) | RLY1: 12 volt AC Relay** Use normally closed (NC) contacts<br>*(Potter & Brumfield KUP-14A15-12)** |
| L1: 5 uH inductor<br>(*Osborn Transformer Part Number 8745*) * | |

** Critical Component, no substitutions permitted without written authorization from the FMC EMC department.*

*** See Table F-1 for relay specifications*

**Figure E-2: Transient Generator (External Connections)**

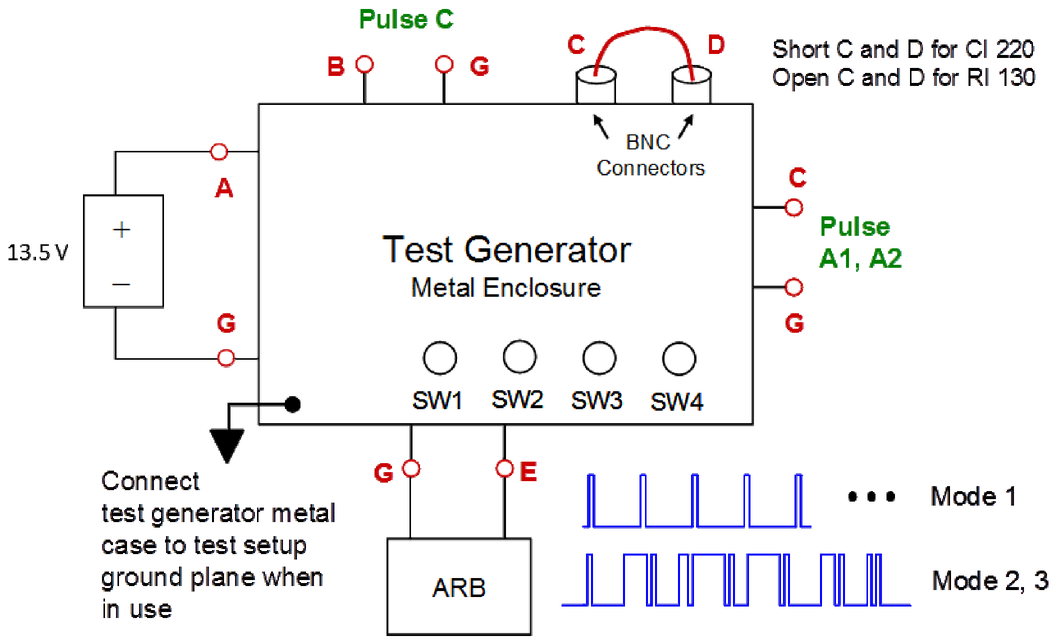



**Table E-1: CI 220 Transient Generator Switch Settings**

| Pulse | Mode * | SW1 | SW2 | SW3 | SW4 |
|---|---|---|---|---|---|
| A1 | 1, 2 | Closed | Closed | Closed | Closed |
| A2-1 | 1, 2 | Closed | Open | Open | Open |
| A2-2 | 1, 2 | Closed | Open | Closed | Open |
| A2-1 | 3 | Open | Open | Open | Open |
| A2-2 | 3 | Open | Open | Closed | Open |
| C-1 | 2 | Closed | Open | Open | Open |
| C-2 | 2 | Closed | Open | Closed | Open |
| C-1 | 3 | Open | Open | Open | Open |
| C-2 | 3 | Open | Open | Closed | Open |

* See Annex D for description of Mode operating conditions

The transient generator uses a Potter and Brumfield (P&B) 12 VAC relay. Specifications for this relay are listed in Table E-2. While the relay is readily available in North America, it may be difficult to locate in other parts of the world.

However, almost any 12 AC relay can be used for this performing testing per this specification. Before using alternative relays, voltage measurements shall be performed and compared to those waveforms illustrated in this annex. The results of these measurements shall be reviewed and approved by the FMC EMC department prior to using an alternative relay.

When using these relays for the purposes delineated in this specification, it is recommended that the relay be replace after 100 hours of usage.

**Table E-2: CI 220 Transient Generator ( P&B Relay Specifications )**

| | |
|---|---|
| Contact Arrangement: | 3 Form C, 3PDT, 3 C/O |
| Contact Current Rating (Amps.): | 10 |
| Coil Magnetic System: | Mono-stable |
| Coil Selection Criteria: | Nominal Voltage |
| Actuating System: | AC |
| Input Voltage (VAC): | 12 |
| Coil Suppression Diode: | Without |
| Coil Resistance (Ω): | 18 |
| Coil Power, Nominal (VA): | 2.70 |
| Mounting Options: | Plain Case |
| Termination Type: | .187 x .020 Quick Connect Terminals |
| Enclosure: | Enclosed |
| Contact Material: | Silver Cadmium Oxide |
| Approved Standards: | UL Recognized, CSA Certified |

## Annex F (Normative): Load Simulator Requirements

The Load Simulator is a shielded enclosure that contains all external electrical interfaces (sensors, loads etc.) normally connected to the DUT. The Load Simulator also serves as an RF boundary for the DUT cable harness in addition to serving as an interface to support and monitoring equipment required during testing.

A typical Load Simulator is illustrated in Figure F-1. The circuits shown serve as examples of what can be contained within the Load Simulator. Actual circuit content is specific to the DUT's functionality. However, the following requirements shall be followed when designing the Load Simulator.

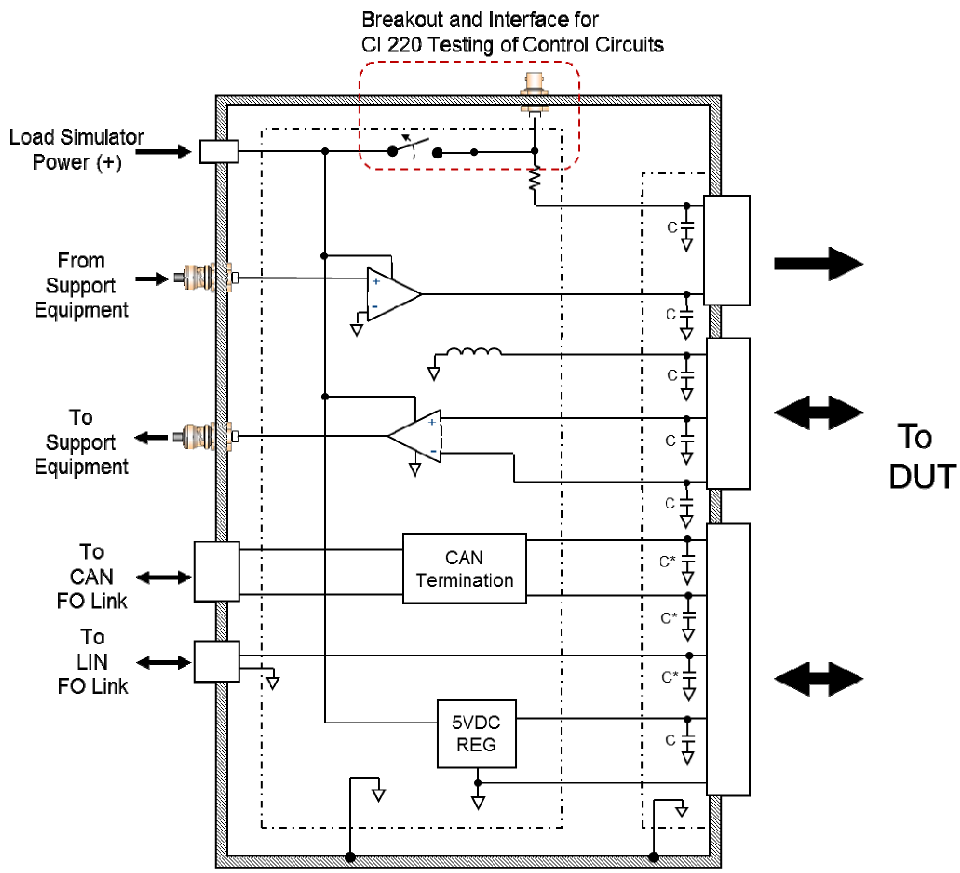
- **All interface circuits within the Load Simulator except CAN shall include a capacitance of 10 nF** located between each interface circuit and the Load Simulator chassis unless actual electrical loads are used. Omission of the 10 nF capacitor shall require approved from the FMC EMC department prior to commencement of testing.. *The 10 nF capacitance value represents the interface capacitance for most modules.* **If the Load Simulator contains a CAN interface (includes MS or HS CAN), the capacitance shall be 470 pf.** The capacitors shall be package as close as possible to the Load Simulator/DUT harness interface connector. Figure F-1 illustrates location of these capacitors. It is recommended to use surface mount capacitors on a separate PCB mounted directly to the interface connectors. This minimizes lead inductance between the interface circuit and Load Simulator chassis. Filter pin connectors may be use, but only with prior approval of the FMC EMC department.
- If the DUT contains CAN communications, the circuits illustrated in Figure F-2 shall be located within the Load Simulator. Configuration A shall be used for devices that contain internal CAN bus termination. Configuration B shall be used for devices that contain no termination.
- Production intent components shall be used for the loads wherever possible. This is particularly critical for inductive and pulse width modulated (PWM) circuits. If actual loads are not available, simulated loads may be used, but shall accurately represent the impedance (resistance, capacitance and inductance) that is expected in a production vehicle. **Simple resistive loads shall not be used unless approved by the FMC EMC department**
- If the DUT is powered from another electronic module (e.g. sensors. Category AS), the module's power supply shall be accurately simulated from within the Load Simulator. Power to these devices may not be supplied from an Artificial Network. Other active devices may be contained within the Load Simulator, but appropriate steps shall be taken to prevent potential influences of RF energy on device operation.
- In general, all inputs and outputs shall be referenced to power ground established at one point within the Load Simulator and connected to the Load Simulator metal chassis.

Figure F-3 illustrates the Load Simulator in a typical test setup.

- The Load Simulator chassis shall be electrically bonded to the test setup ground plane via direct connections (screws) and/or ground straps. Alternative bonding methods (e.g. copper tape with conductive adhesive) is not permitted.
- DUT inputs requiring external signal sources are facilitated via the Load Simulator. Although fiber optic media is recommended for these connections, coaxial cables may be used to connect remote support equipment to the Load Simulator. However, if coaxial connections are used, all cabling shall be have ferrite beads installed on the cable at intervals not exceeding 150 mm. Use of ferrite beads other than the type delineated in Figure F-3 shall be reviewed and approved by the FMC EMC department as part of the laboratory recognition process (see http://www.fordemc.com).
- Fiber optic media shall be used to connect DUT outputs to remotely located monitoring equipment. The frequency bandwidth of the fiber optic media shall be selected to be compatible with the operating bandwidth of the monitored DUT signal, but limited to avoid unintentional RF energy from coupling to, and potentially affecting the test monitoring instrumentation. Use of non-optical interfaces to monitoring equipment is permitted only with prior approval by the FMC EMC department. Details concerning signal monitoring and support equipment interface shall be documented in the EMC test plan
- All fiber optic media shall require prior verification to be immune to the RF stress levels delineated in section 11 of this specification.

Unless otherwise stated for a specific test method, an Artificial Network shall not be used to connect the DUT power return to the power supply negative terminal. This is a deviation to the default setups shown in CISPR 25 and ISO 11452 standards.

**Figure F-1: Load Simulator (Typical Design)**

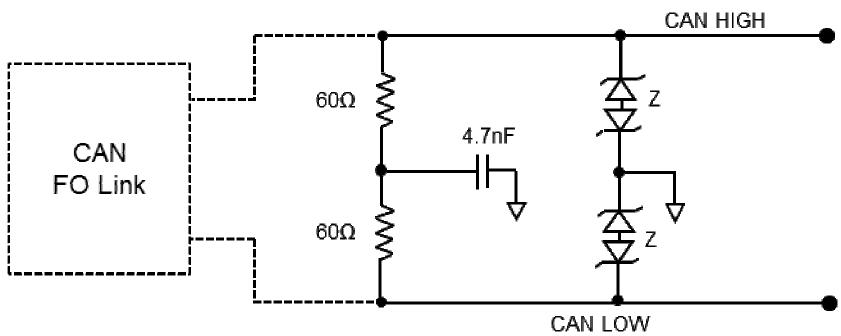



C = 10 nF

*Value is mandatory for all Load Simulator applications unless otherwise* specified in product EMC *specification. Deviation requires approval by FMC EMC department and noted in EMC test plan..*

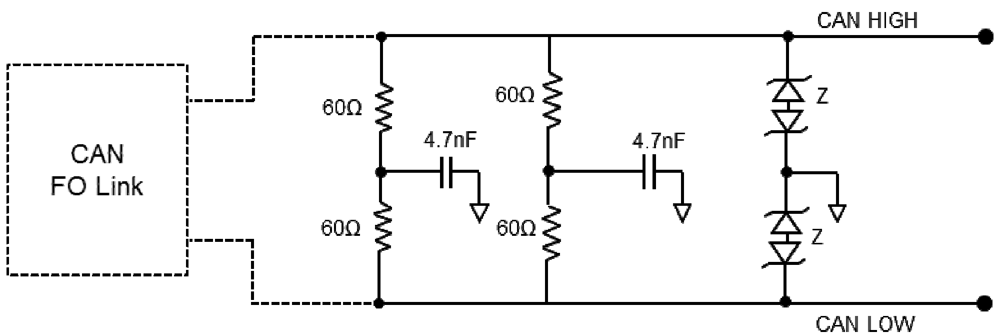
C* = 470 pf (CAN and LIN Interfaces Only)

**Figure F-2: Load Simulator CAN Interface Circuit Design Requirements**




**Configuration A**

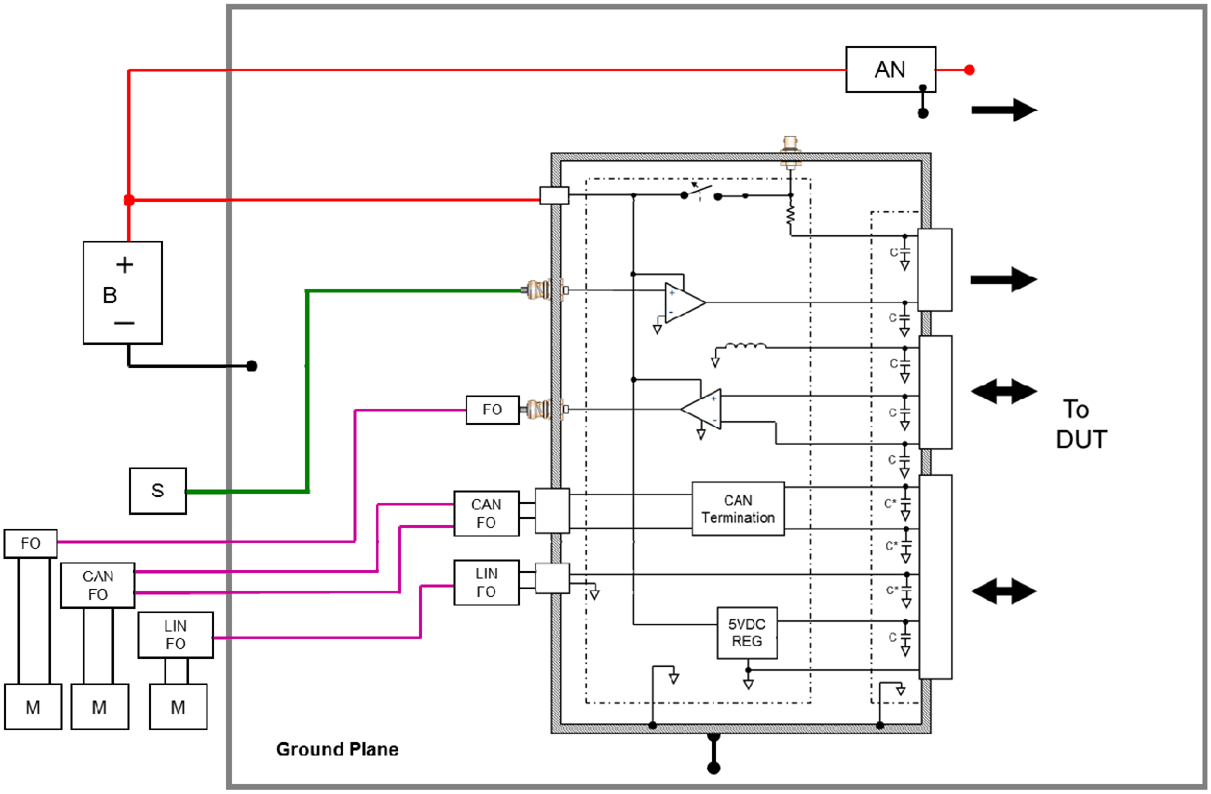
**Devices with internal CAN Termination**




**Configuration B**

**Devices with no internal CAN Termination**

**Figure F-3: Load Simulator Test setup**



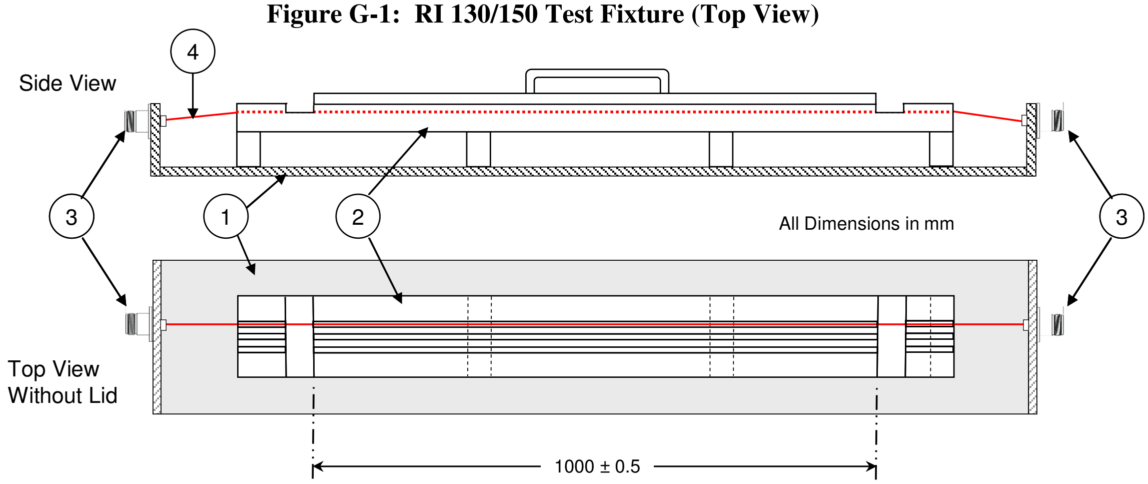

**Key**

| | | | |
|---|---|---|---|
| (symbol) | Signal Ground Reference | (symbol) | Load Simulator Chassis connection to Signal Ground Reference |
| FO | Fiber Optic Media | (symbol) | Ground Plane Electrical Connection |
| M | Monitor Equipment | S | Support Equipment (located outside of test chamber) |
| | | B | Power Supply (See Section 5.5.4)) |

# Annex G (Normative): RI 130, RI 150 Test Fixture and Application

The test fixture used for RI 130 and RI 150 is illustrated in Figure G-1. The fixture consists of a wire support fixture mounted to an aluminum plate. The wire support fixture is constructed from Delrin® 570 NC000. Detailed constructions plans for this fixture may be found at www.fordemc.com.

**Figure G-1: RI 130/150 Test Fixture (Top View)**

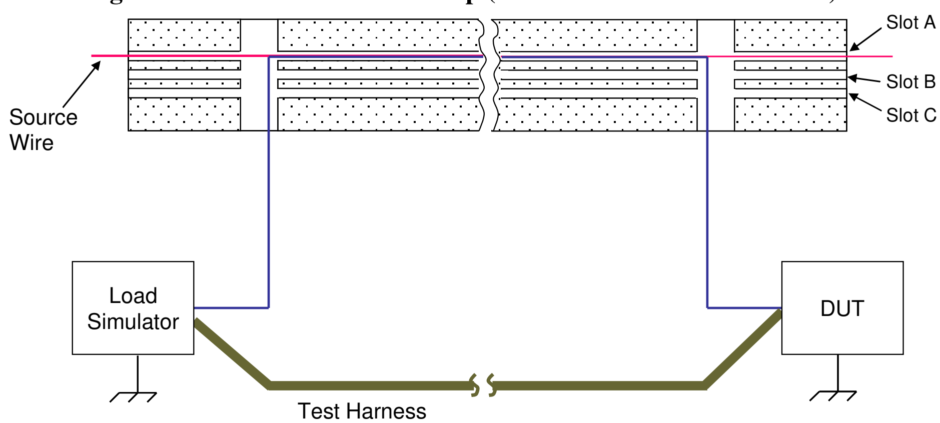



Key

| | |
|---|---|
| Aluminum Plate | Wire Support (Delrin® 570 NC000) |
| Type N Connector | 14 AWG Copper Wire |

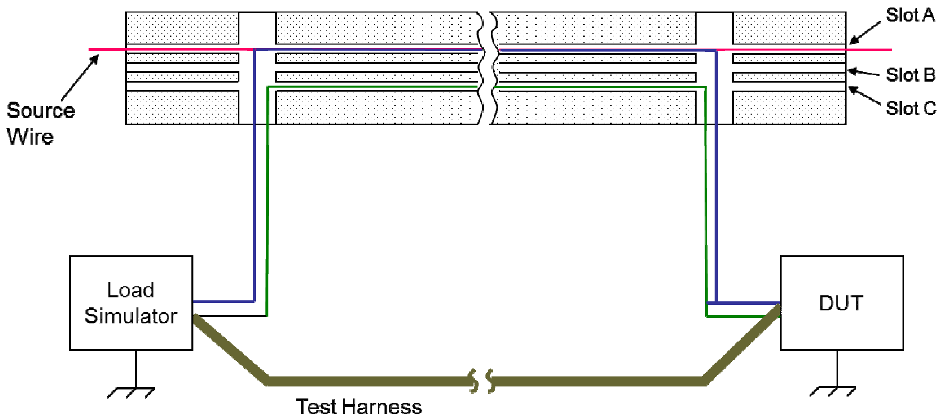
The fixture contains a single copper wire ("source wire") that is connected to the signal source that generates the disturbances for RI 130/RI 150. The DUT is tested by placing individual wires in the slot immediately above the source wire (Slot A). This is illustrated in Figure G-2 below.

**Figure G-2: RI 130/150 Test setup ( Default DUT Wire Location )**



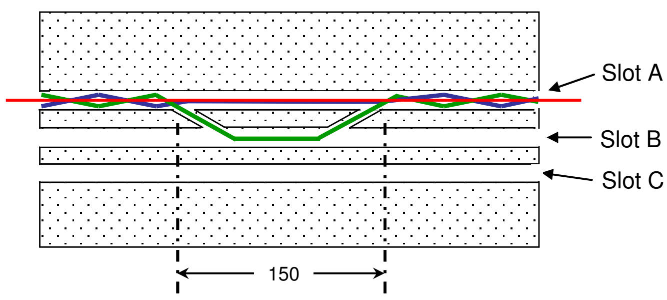

If the DUT contains circuit loads that have a dedicated signal return back to the DUT (*a signal return not shared by any other circuit load)*, each wire of the circuit pair shall be placed in the separate slots (Slots A and C) located in the test fixture as illustrated in Figure G-3. This configuration is typically used for category AS devices. *Dedicated signal returns shall always be located in Slot C unless specified in the EMC test plan. Usage of this configuration requires review/approval by FMC EMC department.*

**Figure G-3: RI 130/150 Test Setup ( DUT with Dedicated Return Wire )**




If the DUT contains twisted pair circuits, each twisted wire pair shall be placed in Slot A as illustrated in Figure G-4. However it is required that the wire pair is untwisted for 150 mm. This is facilitated via the section located in the center test fixture. *The inclusion of this untwisted and unshielded section simulates the device connector or use of an in-line connector.*

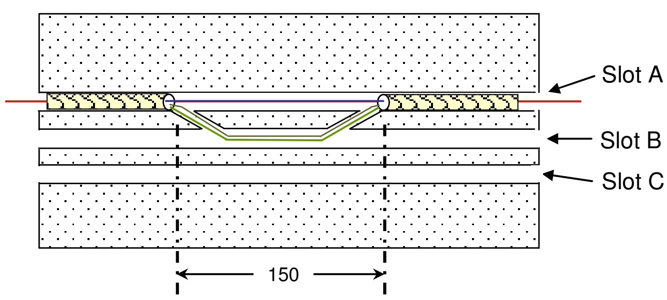
**Figure G-4: RI 130/150 Test setup ( Configuration for a Twisted Wire Pair )**




If the DUT contains shielded circuits includes RF antenna cables), each shielded circuit pair shall be placed in Slot A as illustrated in Figure G-5. However it is required that the circuits are unshielded for 150 mm. This is facilitated via the section located in the center test fixture. The setup is similar to that used for a twisted wire pair.

Note: Slot width limits testing to most shielded twisted pairs and coaxial antenna cables. For larger cables (e.g. shielded/twisted trio), alternative methods must be agreed to by the FMC EMC department. Specific details shall be documented in the EMC test plan.

**Figure G-5: RI 130/150 Test setup ( Configuration for Shielded Twisted Wire Pair )**



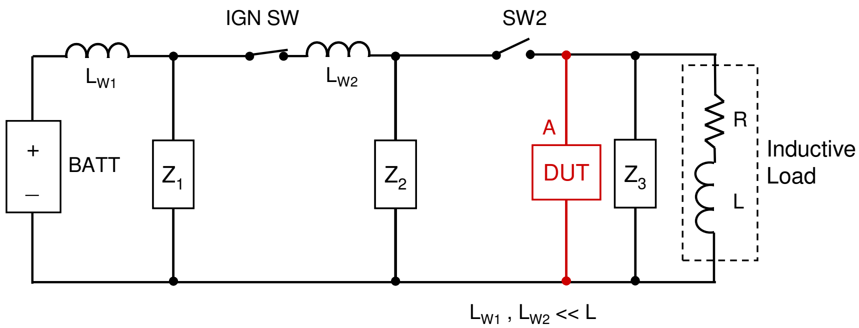
# Annex H (Normative): CI 220 & CI 222 Transient Waveform Application

Application of test pulses A and C in addition to ISO Pulse 1, 5a and 5b are largely dependent on how the DUT is normally connected to the vehicle's power distribution system. This annex provides basic information with respect to application for each transient test pulse. The figures presented represent typical configurations including the ignition switch, remote switch (SW2), inductive load, the DUT and external electronic loads "Z" connected at various points on the power distribution system. Proper application of transient pulses requires analysis of how the actual component (DUT) will be used. In many cases the actual device configuration will be some combination of the generic configurations presented.

Application of ISO pulse 1 for all power supply circuits with increased delay (≥ 30 sec) between consecutive pulses is a special use case related to the vehicle assembly process. During this process, abnormal power supply cycling may occur, causing transient voltages to appear on power supply circuits that would not be normally seen during normal use of the vehicle.

**Configuration 1**

DUT power circuit "A" shares the same circuit as the inductive load (e.g. window lift motor). The DUT and inductive load are switched via SW2. Transient pulses A1, A2 and ISO Pulse 1 will be present at "A" if IGN SW remains closed and SW2 opens. Pulses C and 5a (or 5b) will be present at "A" when IGN SW and SW2 are closed.

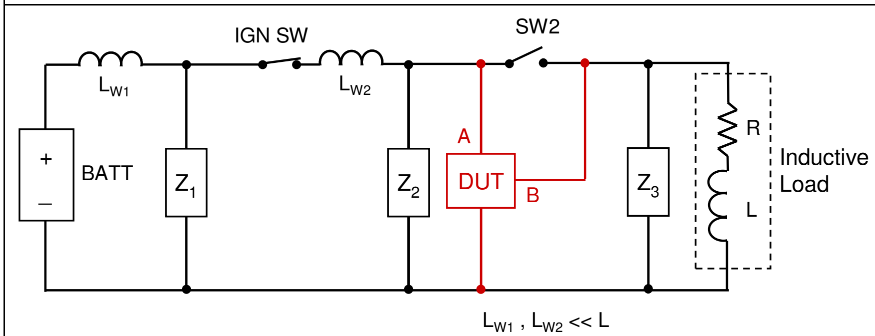



**Pulse Application**

Apply transient pulses A1, A2-1, A2-2, C1, C2 and ISO pulses 1, 5a (or 5b) to DUT power connection "A".

**Configuration 2**

DUT power circuit "A" remains powered when inductive load is deactivated by SW2. The DUT also has an control circuit "B" that is connected to circuit containing inductive load. Transient pulses A1 and A2 will be present at "B" when SW2 opens. Pulse C will be present at "A" if IGN SW remains closed and SW2 opens or bounces Pulses C and ISO pulse 5a (or 5b) will be present at "A" and "B" when IGN SW and SW2 are closed.




**Pulse Application**

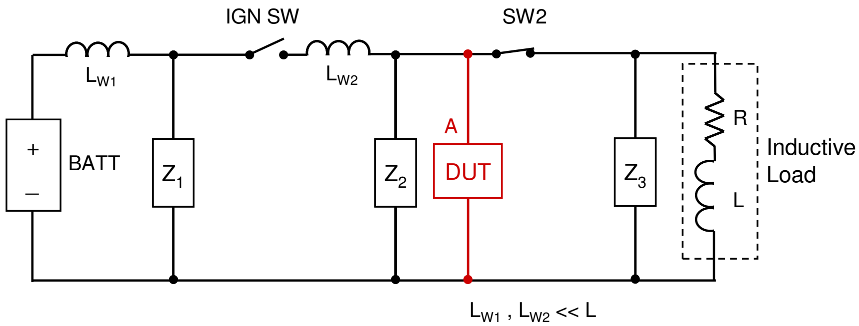
Apply transient pulse C-1, C-2 and ISO pulses 5a (or 5b) to DUT power connection "A".

Apply transient pulses A1, A2-1, A2-2 to DUT input "B".

Apply transient pulse C-1. C-2, and ISO pulses 5a (or 5b) to "A" and "B" simultaneously

**Configuration 3**

DUT power circuit "A" shares same circuit as inductive load when SW2 is closed. The DUT and inductive load are switched via ignition switch or ignition relay. Transient pulses A1, A2 and ISO Pulse 1 will be present at "A" if SW2 remains closed and IGN SW opens. Transient pulse C will be present at "A" if IGN SW remains closed and SW2 opens or bounces. Pulse C and ISO pulse 5a (or 5b) will be present at "A" when IGN SW is closed.

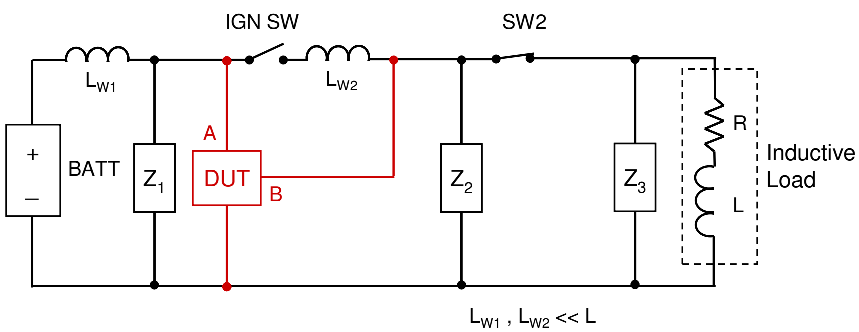



**Pulse Application**

Apply transient pulses A1, A2-1, A2-2, C-1, C-2 and ISO pulses 1, 5A, (or 5b) to DUT power connection "A"

**Configuration 4**

DUT power circuit "A" is directly connected to battery. DUT also has an input or secondary power circuit "B" that is connected to ignition switched circuits. Transient pulse C will be present at "A" if SW2 is closed and IGN SW opens or bounces. Transient pulses A1, A2 and E will be present at "B" if SW2 is closed and IGN SW opens. Pulse C will be present at "B" if IGN SW is closed and SW2 opens or bounces. Pulse C and G (load dump) will be present at "A" and "B" when IGN SW is closed.




**Pulse Application**

Apply transient pulses A1, A2-1, A2-2, C-1, C2 and ISO pulse 1 to "A" and "B" separately

Apply transient pulse C-1, C-2, and ISO pulses 5a (or 5b) to "A" and "B" simultaneously.

# Annex I (Normative): Specification Updates

This annex summarizes differences between this specification and it prior release (FMC 1278, July 1 2015).

Section 2.1: References to specific released international standards have been removed. Only the latest approves standards are referenced.

Section 3.0: Additional abbreviations and acronyms have been included.

Section 4.0, Table 4-2: Status II and III definitions have been modified to differentiate usage of an Ignition (IGN) key cycle.

Section 5.5.4: The power supply shall include an automotive battery in parallel with the regulated supply. This was added to assure power supply stability during testing of devices, whose operation includes high step current changes. Regardless of the DUT, the battery is always present. For emissions testing, a switched mode power supply may be used if it is located outside of the test chamber with adequate filtering at the test chamber interface.

Section 6.2: Clarification of process for test sample selection is provided.

Section 7.0, Table 7-2: CI 22and CI 222 are no longer applicable for category AS devices., CI 220 and CI 280 are now applicable for category BM devices, but per footnote, waiver is possible with supporting analysis. Table 7-2 notes updated to provide clarification of applicability of RI 112/114/115 to Category D devices.

Section 8: Exclusions are allowed for emissions that are the result of transient events or intermittent usage. Exclusions are similar to that already existing for CI 420.

Section 8, Table 8-2: PK limits added to G1 band

Section 8.2.1: In Table 8-3, Dwell time increased from 20 to 50 msec. In Table 8-4, MBW set to 1kHz and dwell time reduced from 20 to 5 msec. Reference to in footnote to band G9 replaced by EU4 (editorial).

Section 8.3, step d): Clarification added to allow assessment using receivers with dual detector capability. Flow charts in Figures 8-2 and 8-3 updated to reflect changes.

Section 9.0: Exceptions expanded to all feature/functions as opposed to focusing only on motor and actuators.

Section 10: Clarifications added about DUTs with metal cases that may be locally connected to vehicle sheet metal.

Section 10.2.1: MBW settings updated to facilitate correct testing over entire frequency range. Footnote added to clarify that non CISPR MBW may be used.

Section 10.2.1: Clarification made that current probe characteristics are “typical” . Clarification also made in Table 10-2.

Section 11.2: Clarification that each DUT power circuit shall be connected to separate Artificial Networks. Untested power circuits shall be directly connected to the power supply

Section 12.1, Table 12-1: Footnotes added addressing performance of RF functions when RF exposed in their operational bandwidth; and performance of diagnostic indications

Section 12.6: Title changed to clarify that RI 114 is applicable from 360 – 3100 MHz.

Section 12.7, Table 12-7: Clarification added for requirements for pulse repetition rate (PRR) and pulse duration (PD). No technical changes to requirement.

Section 12.7.1: Clarification that RF generation equipment, may be located outside or inside test chamber. Figure 12-6 updated to illustrate the different test setups.

Section 12.7.1.1, Table 12-9: Test equipment performance requirements have been updated. Mainline VSWR for directional coupler tightened to 1.25:1. Coupling Port VSWR relaxed (< 1.5:1). Interconnecting cable VSWR set to ≤ 1.1:1. Clarification made that coupling factor must > 20 dB but also compatible with the sensitivity of the measurement equipment used to measure the forward and reflected power.

Section 13.2: Reference for the test method changed from MIL-STD-461E; RS101 to ISO 11452-8.

Section 16, Table 16-1: Clarification that for Level 2, frequency coverage is limited to 0.01 – 10 kHz.

Section 16.2, Table 16-1: Frequency step size added for frequency range from 0.01 to 0.05 kHz. This was mistakenly omitted from prior release of specification.

Section 17.1. Note referencing application of all transients to all power circuits (switched or unswitched) has been removed. Pulse application based on switched or unswitched circuits has been restored which was identical to EMC-CS-2009.1. However, an additional ISO Pulse 1 has been introduced that will be applied to unswitched power circuits but with significantly longer delay between consecutive pulses (≥ 30 sec). Exposure is limited to 5 pulses and Functional Performance is limited to Status IV. This additional requirement was introduced to mimic special conditions only seen during the vehicle manufacturing process. Table 17-1 updated to reflect inclusion of this new pulse. Annex D also updated to document different delay times (0.5 vs ≥ 30 sec). Annex H (formally) Annex E from EMC-CS-2009.1 included to aid in determination of transient pulse application.

Section 17.1, Table 17-1: Foot note (1) clarifies that for Pulse 1, ISO 7537-2 is the reference. Footnote (5) added to DUT operating modes may affect overall current draw, which impacts transient pulse selection.

Section 17.2, bullet point 5: Clarification that individual circuits under test shall remain bundled with the other DUT wiring. This was and still is clearly illustrated in the associated figures.

Seciton18: Scope of requirement now limited to 24 VDC applications.

Section 18.1, Table 18-1: Foot note (1) updated to remove reference to Annex D. ISO 7637-2 is referenced for pulse characteristics.

Section 19.1, Table 19-1: Foot note (3) corrected to state that Us* represents the clamped voltage. Due to changes in test setup, reference to $R_i$=$R_l$ has been removed due to updates in Annex D.

Section 19.2, Figure 19-3: 0.5 ohm shunt resistor ($R_L$) is not used for 24 VDC applications. Also, as is shown in Annex D, the source resistance ($R_i$) is set to 1ohms to be aligned with ISO 7637-2.

Section 19.3: Test procedures updated to reflect differences between testing 12 and 24 VDC systems. Main technical difference is that $R_L$ is not present during testing of 24 VDC systems. Also, $R_L$ and $R_i$ are equal to1 ohm for 24 VDC systems vs 0.5 ohm for 12 VDC systems. Annex D also updated to reflect this difference.

Section 20.2, Figure 20-2: Figures updated to correct error in time $t_1$.

Section 20.3: Test procedures updated to clarify test procedures and state of DUT prior to testing. Figure 20-3 added to show full test sequence. Note added to clarify purpose of test method.

Section 21: Applications of requirement and test limited to 24 VDC systems only. Figure 21-1 updated accordingly.

Section 25.1: 3rd bullet point regarding parametric evaluations removed but move to section 25.3. Footnote added to Table 25-2 stating that testing at ± 15 kV limited to physically accessible devices located in passenger compartment or trunk.

Section 25.2.1: Clarification that all DUT power and logic returns shall be connected to the ground plane via wires with a maximum length of 200 mm.

Section 25.3: Requirement for parametric testing following ESD testing added (move from section 25.1). Additional requirement added that parametric testing can only be performed immediately after ESD testing only if such capability exists within the same test facility. Samples may not be removed from the EMC test facility. If capability does not exist, parametric measurements shall be performed upon completion of all EMC testing listed in the test plan. Alternatively providing additional test samples for ESD testing is recommended to facilitate parametric testing before EMC testing is completed.

Section 25.3.2: Clarification to apply sequence 7 (± 15 kV) for physically accessible devices located in passenger compartment or trunk.

Annex C, Figure C-1: Clarification added that Transmission loss and coupling factor (in dB) is a negative number.

Annex C, Figure C-2: Equation for reflected power updated to correct error. Reflection coefficient in numerator is a squared term.

Annex C, Section C.3: Purpose of section changed to focus on characterization of VSWR of the interconnect cable(s) between the directional coupler and antenna. Figure added to clarify measurement.

Annex C, Section C.4: Section focuses only on characterization of transmission loss of the interconnect cable(s) and directional coupler. Note added to recommend using a single directional coupler to cover the entire frequency band of RI 115. Figure (C-10) added to show typical installation of coupler and power sensors.

Annex D, Figure D-6 through D-12: Table updated to show pulse parameters for 12 and 24 VDC systems. Figure D-11 also shows that transient generator source resistance $R_i$ is 0.5 and 1 ohm for 12 and 24 VDC systems respectively. Previous version of specification used 0.5 ohms for both systems.

Annex E, Table E-1: Table updated to show Mode 1 for Pulse A2-2.

Annex F, bullet point 4: Clarification added that Category AS devices (e.g. sensors), may not be powered through an artificial network. Regulated buffered power from another device shall be accurately simulated within the Load Simulator.

Annex F, bullet point 5: Reference to CI 250 with respect to applying a voltage offset between ground reference of load simulator and ground plan has been removed. The statement pertained to an alternative CI 250 test setup that existed in EMC-CS-2009, but was removed with the introduction of FMC 1278. Removal of the statement in Annex F should have occurred when FMC 1278 was released.

Annex G. Clarification added that configuration shown in Figure G-3 is frequency used for testing of Category AS devices. Permission for use of this configuration requires review/approval by the FMC EMC department and documented in the EMC test plan