General Specification for Electrical/Electronic Components and Subsystems, Electromagnetic Compatibility

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Scope. This document applies to the Electromagnetic Compatibility (EMC) of electrical/electronic components and subsystems for passenger vehicles and light duty trucks.

This document is one out of a series of three global EMC documents, which specify EMC test and validation requirements. The complete series consists of the following documents:

GMW3091, GMW3097, and GMW3103.

1.2 Mission/Theme. This document specifies the EMC requirements for all automotive products when evaluated in accordance with the test procedures contained within this document. It refers to International EMC Standards whenever possible, but also describes internal test procedures if necessary.

1.3 Classification. Not applicable.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

72/245/EEC	ISO 7637-1	ISO 11452-1	ISO 17025
ECE Regulation 10	ISO 7637-2	ISO 11452-2	SAE J1772
IEC 61000-4-21	ISO 7637-3	ISO 11452-4	SAE/USCAR-28
IEC CISPR 25	ISO 10605:2001	ISO 11452-8	

2.2 GM Standards/Specifications.

GMW3059	GMW3091	GMW3103	GMW3172

2.3 Additional References.

CG3044

Component Technical Specification (CTS)

General Motors EMC and Environmental Database (CEMENT)

3 Requirements

Validation results (Design Validation (DV) and Product Validation (PV)) must be obtained only from test sites within a laboratory for specific test procedures that have been recognized through the GM EMC lab recognition process. This process is the replacement for the former Automotive EMC Laboratory Recognition Program (AEMCLRP), which is currently being discontinued.

The GM process will still retain certain specific items from the AEMCLRP, such as:

a. Supplier and third party commercial test labs required to have ISO 17025 accreditation that is obtained from an accreditation body approved by GM. This is generally an accreditation body that has a mutual recognition arrangement (MRA) through the International Laboratory Accreditation Cooperation (ILAC).

b. The scope of accreditation must contain at least the base specifications that apply to GMW EMC test procedures. The base specifications are listed in Table 1.

c. Proficiency test requirements still required, where applicable. This requires testing a defined artifact and comparing results against results obtained at reference laboratory(ies).

Table 1: GM List of Base Specifications (for ISO 17025 Certification)

Procedure Name	Base Specification
Radiated Emissions Anechoic	IEC CISPR 25
Bulk Current Injection	ISO 11452-4
Radiated Immunity Anechoic	ISO 11452-2
Radiated Immunity Reverb	IEC 61000-4-21
Transient Immunity	ISO 7637-2 and ISO 7637-3
Electrostatic Discharge	ISO 10605:2001

For more information on the GM EMC laboratory recognition requirements, as well as a listing of those laboratories recognized by GM, visit the public forums section on the SAE International web site. As of the time of this publication, this web site address is:

http://forums.sae.org/access/dispatch.cgi/tevemc_pf/folderFrame/100004

Effective January, 2011, suppliers shall utilize the General Motors EMC and Environmental Database (CEMENT), available via GM Supply Power. The suppliers shall adhere to the following:

a. Register with the EMC database through GM Supply Power and take the appropriate training within 4 weeks following sourcing.
b. Register all components (e.g., each individual part number released for production) associated with the DV EMC testing into the database within 4 weeks following sourcing.
c. Submit (Upload) Initial GMW3103 EMC Test Plan for approval by the GM EMC engineer within 12 weeks following sourcing, but no less than 60 days prior to the start of any DV/PV EMC testing. This allows sufficient times for expected revisions, etc. Any/all subsequent revisions to the same level plan (e.g., DV1, DV2, etc., up to the n^{th} PV plan (PVn)) shall be uploaded to CEMENT, replacing the previous version. However, the test plan development timing must be such that a final test plan submittal occurs at least 10 business days prior to the start of any testing, allowing sufficient time for the GM EMC Engineer to review and approve the document.
d. Submit (e.g., upload to CEMENT), for each required procedure, a report which contains all data, photos, summary, etc., within 30 days of completion of the specific testing for that procedure. Unless otherwise agreed to by the GM responsible engineer, all of these reports must be submitted at least 10 business days prior to the data approval date (as determined by the GM responsible engineer and/or GM responsible validation engineer for the specific component). This allows sufficient time for the GM EMC engineer to review and approve the datasets.

Note: The GMW3103 EMC Test Plan (e.g., Appendix A of this standard) is available in an editable, uncontrolled release from the GM EMC Engineer via the reference document CG3044 in the GM Global Document Management (GDM) database.

Note: In addition to the procedure report(s) per item d. above, the supplier shall also submit a brief summary of any/all DV/PV data associated with any test under an approved EMC test plan within 5 working days of completion of that testing. This submission shall be via email to both the GM Design Responsible Engineer (DRE)/Designing Engineer (DE) and the GM EMC Engineer. (Presently, the CEMENT application cannot be used to submit partial summaries.)

Note: The timing requirements specified here supplement, but do not supersede or replace Analysis Development Validation (ADV) program timing requirements specified in other GM documents and engineering standards such as GMW3172.

Note: DV testing must be successfully completed prior to the Integration Vehicle Engineering Release - Material Required Date (IVER MRD), unless otherwise specified by the individual component technical specification (CTS).

Figure 1 is shown as a summary of the expected timing milestone.

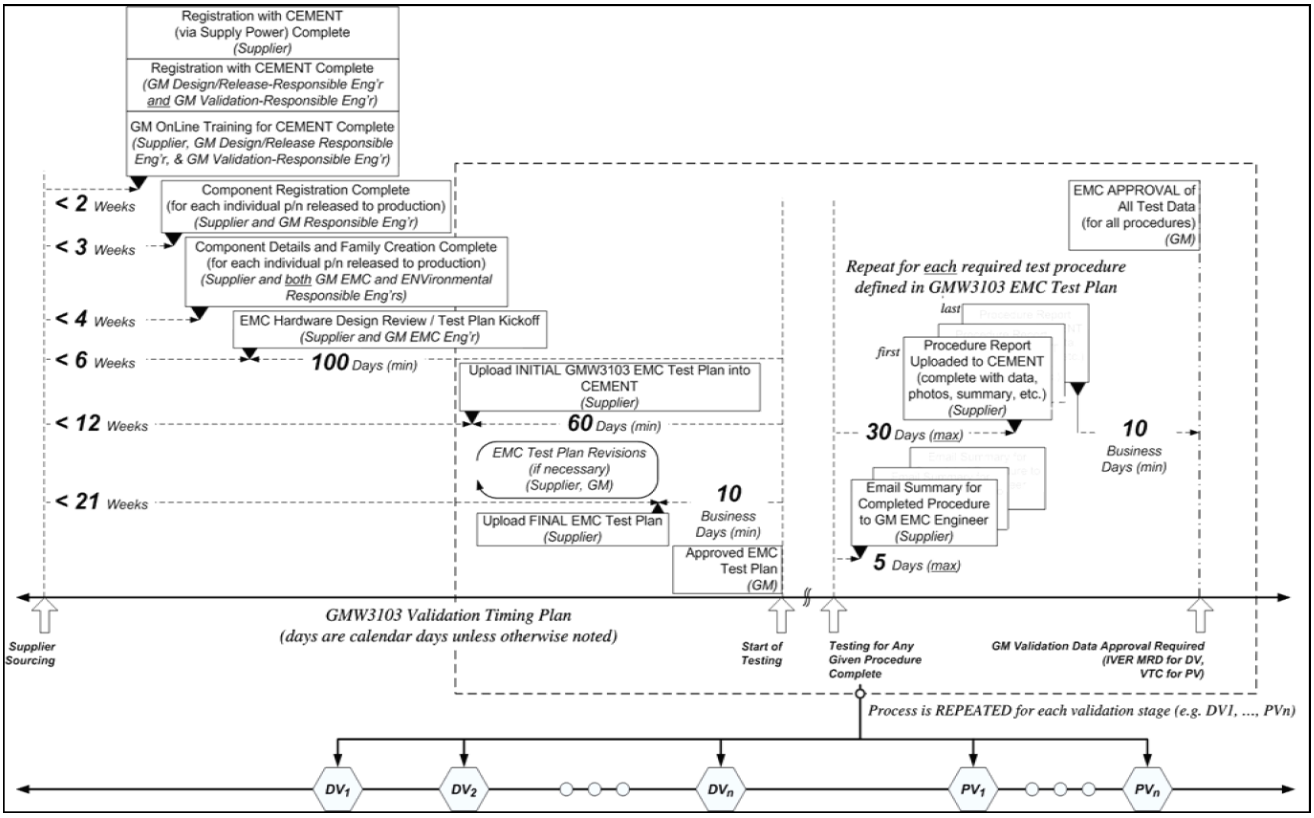


Figure 1: CEMENT Database Timing Milestones

3.1 Product Characteristics.

3.1.1 Sample Size. A minimum of two (2) samples shall be tested. The actual number of samples must be defined together with the GM EMC Engineer. All samples must comply with the requirements of this document for all validation items as defined in the GMW3103 test plan. If more than 2 samples are tested, all results shall be reported and all results must comply.

3.1.2 Power Supply. As an exception to the international standards, the supply voltage shall be (13.5 +0.5/-1.0) V, unless otherwise stated in the test plan.

3.2 Performance Requirements. The Device Under Test (DUT) shall pass both the component level tests according to this specification and the vehicle level tests according to GMW3091. Component tests are not intended to take the place of vehicle tests. Exact correlation between component and vehicle test performance is dependent on component mounting location, harness length, routing and grounding, as well as antenna system. Component testing, however, permits components to be evaluated prior to actual vehicle availability.

Prior to testing, any deviations from the requirements and/or test procedures shall have been agreed with the GM EMC Engineer responsible for approving the test plan. Such deviations shall be detailed in the approved test plan and on component drawings, test certificates, reports, etc.

Table 2 is supplied as a guide for the selection of the minimum tests applicable to electrical/electronic components and subsystems. The result of following this table may not be all inclusive. The final list of required tests is to be determined by the EMC Engineer during the GMW3103 process.

Note: All EMC test results that are intended for validation purposes must be accompanied by a GMW3103 EMC Test Plan (complete with an approval number supplied by the GM EMC Engineer or by the CEMENT database process). Every page of the Test Plan shall include a revision reference that is tied to the approval page.

Note: Any EMC development test results that are provided to GM (e.g., test results that have been taken before the EMC test plan approval, or results of limited testing due to root cause analysis or Pre-DV evaluation work) must be clearly marked “Development Data – Not For Validation”.

Note: Pyrotechnic devices containing igniters, such as airbag initiators, seat-belt pretensioners, etc., are exempt from the EMC requirements as detailed in this specification. They are subject to the EMC requirements as detailed in SAE/USCAR-28.

Note: For those devices, such as the On-Board Charging Module (OBCM) or off-board chargers, which are directly connected to the Alternating Current (AC) or Direct Current (DC) power mains while charging an electric/hybrid vehicle, additional and unique EMC requirements shall be imposed in order that the vehicle is compliant with the newer release of ECE Regulation 10 pertaining to plug-in vehicles. Some of these requirements are similar to those found in SAE J1772 pertaining to electric and hybrid conductive charge couplers. These additional requirements shall be captured in the specific CTS for those devices and are outside the scope of this document at this time.

In this document, electronic modules, electric motors and inductive devices are classified into categories that determine the appropriate test requirements. This category shall be documented in the test plan.

For all tests the more stringent requirement applies at frequency breakpoints and overlaps.

Additionally, Table 3 contains specific EMC design requirements for some categories of devices which shall be validated by inspection (e.g., no testing required). Compliance to these requirements shall be documented in the test report.

Table 2: EMC Test Selection Matrix Note 1

Test		Paragraph Numbers	Electronic Module Categories								
			Others		Electronic Components					Motors	
			D	**R**	**A**	**AS**	**AM**	**AX**	**AW**	**BM**	**EM**
Emissions 3.3	ALSE CE, Artificial Network	3.3.1 3.3.2			X	X	X	X		X **Note 2**	X
	Magnetic Fields (PEPS LF) **Note 3**	3.3.3			X		X	X		X **Note 4**	X
Immunity 3.4	Bulk Current Injection Anechoic Chamber Reverb, Mode Tuning	3.4.1 3.4.2 3.4.3	X **Note 5** **Note 6**		X	X	X	X	X **Note 7**		X
	Powerline Magnetic Fields	3.4.4					X				X **Note 8**
Transients 3.5	Conducted Emissions	3.5.1		X						X	
	CI, Power Lines only	3.5.2	X		X		X	X			X
	CI, Coupling to I/O Other than Power Supply Lines	3.5.3			X	X	X	X			X
	CI, Direct Capacitive Coupling to Sensor Lines	3.5.4				X					
	CI, Coupling to I/O (85 V)	3.5.5			X	X	X	X			X
	CI, Alternator Direct Capacitor Coupling	3.5.6						X **Note 9**			
ESD 3.6	Powered-On Mode	3.6.1			X	X	X	X			
	Remote I/O	3.6.2	X **Note 10**	X	X		X	X			
	Handling of Devices	3.6.3	X		X	X	X	X	X		X

Note 1: Table 2 is supplied as a guide for the selection of the minimum tests applicable to electrical/electronic components and subsystems. The result of following this selection matrix may not be all inclusive. The final list of required tests is to be determined by the EMC Engineer during the GMW3103 process.

Note 2: Momentary-operating motors/actuators such as door lock and trunk actuators (e.g., typically less than 1 second), as well as engine starter motors, are exempt from radiated emissions and conducted emissions (via artificial network) requirements**.**

Note 3: This requirement applies only to those modules or components which are located in the passenger compartment and that can be placed in the close proximity to cup holders, storage compartments, the glove box, etc., where key fobs for the passive-entry, passive-start (PEPS) system may be placed by the driver. Additionally, this requirement applies only to those devices which do not utilize a full metallic enclosure. This requirement would not be applicable to, for instance, engine controllers, transmissions controllers, fuel pump control modules, etc.

Note 4: This requirement applies only to pulse width modulated (PWM) DC brush-commutated motors.

Note 5: Test does not apply to a mechanical switch incorporating a simple resistor or resistor-ladder network.

Note 6: This requirement can be “validated by inspection” for those D-Category devices whose light emitting diodes (LED) are used exclusively for backlighting (e.g., not used for indication of position, switch selection, etc.) where there is either a capacitor, or package-protection for a capacitor, across the LEDs specifically to address EMC concerns.

Note 7: Requirements/testing shall be mutually agreed upon by the component supplier and the GM EMC Engineer and documented in the EMC test plan.

Note 8: Applies only to motors with integral Hall Effect sensors.

Note 9: This requirement is applicable only to alternators/generators.

Note 10: This requirement may not apply to a remote NTC/PTC used for temperature sensing, since these are typically not available to an occupant from inside or outside of the vehicle.

Electronic Module Categories:

A	A component or module that contains active electronic devices. Examples: analog op-amp circuits, switching power supplies, microprocessor controllers and displays.
AM	An electronic component or module that contains magnetically sensitive elements.
AS	An electronic component or module operated from a regulated power source in another module. This is usually a sensor providing input to a controller.
AX	An electronic module that controls an inductive device (e.g., DC-Brush motors or electronically controlled motor(s), solenoids, etc.) internal or external to its package.
AW	An electronic module that contains an RF TX/RX and an internal battery power source and does not incorporate an integral external cable harness or an external electrical connector to enable connection to a vehicle cable harness (e.g., Key Fob, tire pressure sensor).
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.)

Electric Motors:

BM	A brush commutated electric motor.
EM	A brushless commutated electric motor.

Inductive Devices:

R	Relays and solenoids and conventional electromechanical horns.

Table 3: Specific EMC Design Validation Requirements for Devices

Validation by Inspection		Paragraph Numbers	Others		Electronic Components					Motors	
			D	R	A	AS	AM	AX	AW	BM	EM
Specific EMC Design Requirements 3.7	Restriction of Motor Capacitance	3.7.1						X		X	
	BM Glass Wipers, HVAC Blower Motor, and Fuel Pump Capacitance And Diode	3.7.2						X Note 1		X Note 1	
	Package Protection - Short-Duration Motor Inductors	3.7.3								X	
	Package Protection - Short-Duration BM Motor Transient Voltage Suppression	3.7.4								X	
	Static Charge Bleed-Off Resistor Present (DUTs with DC-Isolated Metallic Cases)	3.7.5			X	X	X	X	X		
	Package-Protection – NTC/PTC Shunt Capacitor Note 2	3.7.6	X		X	X	X				

Note 1: Transient voltage diode clamp requirement applies to the motor control circuit (e.g., may be installed in the electrical center, the wiring, or the motor itself).
Note 2: This requirement applies to those NTC/PTC applications which are used as remote temperature sensing elements and not internal to an electrical/electronic module.

3.2.1 Report. The supplier is required to submit the applicable validation test results in the format provided by the authorized test laboratory in their entirety without modifications.

All test reports shall include the following elements in addition to the report elements specified in each section:

3.2.1.1 Regarding Supplier.

- Requesting engineer.
- Requesting division/company.
- Type of test (Design Validation or Product Validation).

Note: Each page of the test report must be clearly labeled as a validation report (Design Validation or Product Validation) or as a development report (Development Only – Not for Sign Off). This may be included in a header or footer. For development reports, a watermark (that does not obstruct data) is preferred.

3.2.1.2 Regarding Test Plan.

- A copy of the GM approved EMC Test Plan (per GMW3103), complete with the EMC Test Plan approval number (as supplied with the GMW3103 Test Plan by either the CEMENT database or the GM EMC engineer) shall be included in the Test Report submitted to GM.
- DUT Category (from the Test Selection Matrix and as documented in the test plan).

Any deviation from the approved test plan and any applicable standards, including, but not limited to, test setup and test procedure. Any data obtained from testing where there are deviations to the approved test plan and applicable standards that are not approved by the GM EMC Engineer shall not be published in a validation (DV or PV) report.

3.2.1.3 Regarding Equipment/Setup.

- Internal unique test report number.
- Date(s) of test (for each test performed).

  Note: Test results obtained from testing performed prior to test plan approval shall not be published in a validation report.
- Facility name (including the test site designations where the tests were performed).
- A listing of equipment used for each test run including the manufacturer, make and model, and calibration due dates.
- Test Equipment Software Revision (if test equipment is software controlled).
- Any deviation from the requirements of this engineering standard, including, but not limited to, test setup and test procedure.
- Description of the test set-up and equipment used.
- A unique identification number must be assigned to the sample along with a description of the DUT and harness, including Hardware and Software Version. All data must include a reference to the sample tested.
- Block diagram showing the DUT setup, including all lab equipment used to perform the test.

  Note: Do not use the simplified block diagrams as found in any of the reference standards. Those figures are generic, by nature, and cannot show the details required by a DUT-specific Test Plan.
- Part number and description of the harness.
- Photographs with sufficient clarity to enable compliance with the test plan to be verified. The details shown in photographs must include, **but not be limited to**, those details described below **as applicable** for each test performed:
  a. The DUT, harness, simulator and fiber optic transmitters/modules resting above the ground plane on insulating material.
  b. The connections between the battery and the Artificial Networks (AN).
  c. The connections between the simulator and the DUT-side of the ANs.
  d. The connections between the DUT and the simulator.
  e. The connections between any power supplies and any fiber optic transmitters/modules requiring external supplies.
  f. A close-up of the connection of any communication bus fiber optic device to the test harness, including, for instance, the position of MASTER/SLAVE switch for the Local Interconnect Network (LIN) Bus (if applicable).
  g. Bonding of the negative battery lead to the ground plane.
  h. All interfaces that connect to leads exiting test chamber walls.
  i. Any DUT monitoring equipment located outside test chambers and its connection through chamber walls.
  j. Bulk Current Injection (BCI) injection clamp supported above the ground plane and the harness routed through the clamp.
  k. Connections between transient generators, monitoring equipment, and the DUT.
  l. Bonding of the transient generator to the ground plane.
  m. Coupling capacitors and the test injection point at the DUT.
  n. The transient capacitive coupling clamp resting on the ground plane, the bonding of the transient generator to the ground plane and the routing of the harness through the clamp.
  o. The connections between the transient generator and the capacitive coupling clamp.
  p. DUT resting above the ground plane on a static dissipative mat (Electrostatic Discharge (ESD) Handling of Devices test).
  q. Bleed-off resistor and its connection to the ground plane (ESD Handling of Devices test).

3.3 Emissions. This section deals specifically with the unintentional radio frequency (RF) emissions of a DUT. For these emissions, both radiated emissions (RE) and conducted emissions (CE) via an artificial network (AN) metrics apply.

Additionally, limits are also placed on the near-field magnetic fields of certain types of DUTs. The unintentional emissions of a DUT can be in the form of low-frequency (LF) magnetic fields that can adversely impact the LF operation of the PEPS subsystem. This requirement applies only to those modules or components which are located in the passenger compartment and that can be placed in close proximity to cup holders, storage compartments, the glove box, etc., where key fobs for the PEPS subsystem may be placed by the driver. This requirement does not apply to those devices which utilize a full metallic enclosure.

With respect to the RE and CE via AN measurements and limits, the following statements apply:

- Noise is divided into three different types:
    1. Non-spark generated noise: Noise generated by electronic sources, such as microprocessors, clocks, PWM, etc.
    2. Combination of non-spark and spark generated noise. This noise contains contributions from a PWM driving a motor and motor brush noise.
    3. Spark generated noise: Noise generated by sparks, such as ignition systems, short and long duration brush type motors, etc. For the purpose of this standard, short-duration brush type motors are defined as those motors that cannot operate continuously while driving the vehicle. Examples include window motors, seat adjustment motors, mirror motors, secondary air pumps, load-leveling compressors, etc. Long (continuous) duration brush type motors are defined as those motors that can operate continuously while driving the vehicle. Examples include engine cooling fans, wipers, fuel pumps, and HVAC blower motors.
- The radiated emissions requirements comprise (2) parts:
    1. A complete coverage requirement for the 30 MHz to 1000 MHz band, derived from the European EMC regulatory requirements of 72/245/EEC and ECE Regulation 10 for electronic sub-assemblies;
    2. A more restrictive set of requirements for individual onboard receiver bands, based on specific customer requirements.
- For the onboard receiver bands, there is an additional 1% guard band included in the table values for those receiver bands between 30 MHz and 240 MHz. This is to be able to establish risk of emissions “drift”. Emissions that exist within this 1% guard band are to be included in the final report.
- Emissions may be captured in the individual receiver bands or from 530 kHz to 2351 MHz, or in any other appropriate number of sub bands.
- The Non-Spark requirements of both Table 4 and Table 7 are applicable to the following Categories: A, AS, AM, EM, AX, AX with EM, AX with BM (as a complete subsystem, for both Continuous and Short-Duration).
- The Spark requirements of both Table 5 and Table 8 are applicable to the following Categories: BM (Continuous), AX with BM (as a complete subsystem for Continuous).
- The Spark requirements of both Table 6 and Table 8 are applicable to the following Categories: BM (Short-Duration), AX with BM (as a complete subsystem for Short-Duration).

Note: Motors, such as door lock motors and trunk actuators (which typically are energized for less than 1 second and are activated by the driver/occupant) are exempt from the radiated and conducted emissions requirements of this section.

Note: AX with BM implies a PWM motor control subsystem and not simply an AX device controlling BM motors via relays.

- The use of a Peak (PK) detector at the same or greater resolution bandwidth (RBW) is allowed as a quick pre-screen in all bands to increase testing efficiency. If the PK emissions are below the appropriate requirement(s), the test data may be submitted as the final result. If the PK emissions are above the requirement(s), it will be necessary to re-sweep the entire band using the specified bandwidth and detector.
- Quasi-Peak (QP) detector is typically used for measurement of “Spark” generated emissions.

3.3.1 RE, Absorber Lined Shielded Enclosure (ALSE). Prior to measuring the DUT emissions for RE, measurement of the ambient levels (i.e., load box, simulator energized with DUT connected but unpowered) is required. The ambient levels shall not be above the limit and should be at least 6 dB below the limit. This data shall be supplied within the test report.

3.3.1.1 Equipment. The test equipment shall comply with the requirements of IEC CISPR 25.

Note: As a deviation from IEC CISPR 25 for a remotely-grounded DUT, the simulator/load box shall rest on an insulation support above the ground plane. The insulation support shall have same thickness and other characteristics as that specified for the DUT by IEC CISPR 25. In accordance with IEC CISPR 25, the simulator shall be powered via the artificial networks.

Note: For this test, if a laboratory is unable to have the full length of the harness straight along the edge of the table, the harness shall be kept straight for a length of 1500 mm, minimum, from the DUT. The remaining wire length to the simulator and/or artificial networks shall not be coiled and shall be kept at least 5 cm from either the walls or the edge of the table.

Preamplifier/Preselector: Due to the extremely low level signals that must be observed, a preamplifier (or preselector) may be required ahead of the receiver to improve the system sensitivity.

No DUT I/O filtering or power supply filtering shall be permitted within the simulator, except as provided for the intended load interface definition for the DUT (as detailed in the GMW3103 EMC Test Plan).

3.3.1.2 Procedure.

3.3.1.2.1 Regarding DUT Orientation.

- Below 30 MHz a single DUT orientation shall be used unless otherwise specified in the test plan. If the DUT side that will face the vehicle antenna in a vehicle installation is known, that orientation shall be used. If this is unknown (i.e., for inaccessible devices where the mounting orientations vary), select a convenient orientation.
- Above 30 MHz, three orthogonal DUT orientations are required unless otherwise specified in the test plan.

3.3.1.2.2 Regarding Antenna Polarization.

- Below 30 MHz, a single vertical antenna polarization is required.
- Above 30 MHz, both horizontal and vertical polarizations are used.

The maximum level at each frequency (for all DUT orientations and antenna polarization(s)) shall be reported.

For the frequency range 1 GHz to 2 GHz, the receiving antenna shall be moved 0.75 m parallel to the front edge of the ground plane towards the DUT in order to point at the DUT instead of the center of the wiring harness.

3.3.1.3 Requirements. The field strength level of the radiated emissions shall not exceed the levels of Table 4, Table 5, and Table 6.

Table 4: Radiated Emissions Absorber Lined Chamber (ALSE) Non-Spark Requirements

ID Number	Region	RF Service (User Band) (MHz)	Frequency Range (MHz)	Conditions	Non-Spark Limit (dBµV/m)	Note
M1	Global	Not Applicable	30 to 75	RBW 120 kHz, Step Size ≤ 60 kHz, Time/Step ≥ 5 ms	52 - 25.13*Log(f/30); f in MHz, AV	
M2	Global	Not Applicable	75 to 400		42 + 15.13*Log(f /75); f in MHz, AV	
M3	Global	Not Applicable	400 to 1000		53 AV	
G1	Global	Medium Wave /AM	0.53 to 1.71	RBW 9/10 kHz, Step Size ≤ 5 kHz, Time/Step ≥ 50 ms	30 PK (24 AV)	1
NA1	GMNA	TexDoT (45.68 to 47.34)	45.2 to 47.8	RBW 9/10 kHz, Step Size ≤ 5 kHz, Time/Step ≥ 5 ms	20 PK + 12 AV	2, 3
EU1	GME, GMH	4 Meter (66 to 87.2)	65.2 to 88.1		20 PK + 12 AV	2, 3
JA1	Japan	FM I (76 to 90)	75.2 to 90.9		20 PK + 12 AV	2, 3
G2	Global	FM II (87.5 to 108)	86.6 to 109.1		20 PK + 12 AV	2, 3
G3	Global	2 Meter (142 to 175)	140.6 to 176.3		20 PK + 12 AV	2, 3
G4	GME, GMH	DAB (174.1 to 240)	172.4 to 242.4		20 PK + 12 AV	2, 3
G5	Global	RFA/TPMS I	310 to 320		20 PK	
G6	Global	RFA/TPMS II	429 to 439		25 PK	
EU3a	GME	Tetra (Emergency)	380 to 385 390 to 395		2 AV	
EU3b	GME	Tetra (Emergency)	410 to 412 420 to 422		8 AV	
G7	Global	Tetra (Civil)	385 to 390 395 to 410 412 to 420 422 to 430		18 AV	
G8	Global	GPS	1567 to 1574 and 1576 to 1583		50 to 10 and 10 to 50 AV	4, 5

Note 1: The Average (AV) detector limit applies only when testing a category "AX with BM" subsystem (i.e., PWM DC brush-commutated motors). The average detector is necessary as a result of the lack of filtering capacitance in the motor (in order to avoid large inrush currents during the PWM operation). Compliance to this AV detector limit requires that the component or subsystem be configured for a nominal 60% duty cycle (unless otherwise specified in the test plan) **and** with an actual BM load (e.g., not an R-L-C equivalent).
Note 2: Frequency Range includes a 1% guard band surrounding the User Bands between 30 MHz and 240 MHz.
Note 3: The DUT must pass BOTH limits (e.g., PK and AV) in these bands.
Note 4: Bandwidth reduction or a high gain low noise amplifier should be used in order to accurately measure these low signal levels.
Note 5: Requirement is 50 dBµV/m at 1567 MHz, decreasing linearly in frequency to 10 dBµV/m at 1574 MHz, 10 dBµV/m between 1574 MHz and 1576 MHz, 10 dBµV/m at 1576 MHz increasing linearly in frequency to 50 dBµV/m at 1583 MHz.

Table 5: Radiated Emissions Absorber Lined Chamber (ALSE) Spark Requirements (not applicable to short-duration motors)

ID Number	Region	RF Service (User Bands) (MHz)	Frequency Range (MHz)	Conditions	Spark Limit (dBµV/m)	Note
M1	Global	Not Applicable	30 to 75	RBW 120 kHz, Step Size ≤ 60 kHz, Time/Step = 1 s	62 - 25.13*Log(f/30); f in MHz, QP	4
M2	Global	Not Applicable	75 to 400		52 + 15.13*Log(f /75); f in MHz, QP	4
M3	Global	Not Applicable	400 to 1000		63 QP	4
G1	Global	Medium Wave /AM	0.53 to 1.71	RBW 9 kHz, Step Size ≤ 50 kHz, Time/Step = 1 s	54 QP	3
NA1	GMNA	DoT I (45.68 to 47.34)	45.2 to 47.8	RBW 120 kHz, Step Size ≤ 1 MHz, Time/Step = 1 s	24 QP	1, 2, 3
EU1	GME, GMH	4 Meter (66 to 87.2)	65.2 to 88.1		24 QP	1, 2, 3
JA1	Japan	FM I (76 to 90)	75.2 to 90.9		24 QP	1, 2, 3
G2	Global	FM II (87.5 to 108)	86.6 to 109.1		24 QP	1, 2, 3
G3	Global	2 Meter (142 to 175)	140.6 to 176.3		24 QP	1, 2, 3
G4	GME, GMH	DAB (174.1 to 240)	172.4 to 242.4		24 QP	1, 2, 3
G5	Global	RFA/TPMS I	310 to 320		30 QP	1, 3
G6	Global	RFA/TPMS II	429 to 439		30 QP	1, 3

Note 1: For QP measurements, the Time/Step may be greater than 1 s to increase repeatability.

Note 2: Frequency Range includes a 1% guard band surrounding the User Bands between 30 MHz and 240 MHz.

Note 3: If testing a category "AX with BM" component or subsystem (i.e., PWM DC brush-commutated motors), compliance to the spark requirements as shown in this table requires that the component or subsystem be configured for 100% duty cycle (unless otherwise specified in the test plan) **and** with an actual BM load (e.g., not an R-L-C equivalent). Because the motor load cannot have any significant capacitance installed when using a high-current PWM feed, the BM motor performance can only be assessed when tested as a subsystem with the AX controller.

Note 4: The use of a PK detector at the same or greater RBW is allowed (and recommended) as a quick pre-screen in all bands to increase testing efficiency. The time/step for a PK detector pre-sweep is allowed to be 5 ms. If the PK emissions are below the appropriate requirement(s) the test data may be submitted as the final result. If the PK emissions are above the requirement(s), it will be necessary to re-sweep those frequency(ies) using the QP detector.

Table 6: Radiated Emissions Absorber Lined Chamber (ALSE) Spark Requirements Short Duration BM Motors

ID Number	Region	RF Service (User Band) (MHz)	Frequency Range (MHz)	Conditions	Spark Limit (dBµV/m)	Note
G1	Global	Medium Wave /AM	0.53 to 1.71	RBW 9 kHz, Step Size ≤ 50 kHz, Time/Step = 1 s	54 QP	1, 2, 4
JA1	Japan	FM I (76 to 90)	75.2 to 90.9	RBW 120 kHz, Step Size ≤ 1 MHz, Time/Step = 1 s	24 QP	1, 2, 3, 4
G2	Global	FM II (87.5 to 108)	86.6 to 109.1		24 QP	1, 2, 3, 4
G4	GME, GMH	DAB (174.1 to 240)	172.4 to 242.4		24 QP	1, 2, 3, 4

Note 1: Door lock motors, trunk actuators, etc. (which typically are energized for less than 1 second and activated by the driver/occupant) are exempt from the conducted emissions requirements. Starter motors, as a specific device, are also included in this exemption.
Note 2: For QP measurements, the Time/Step may be greater than 1 second to increase repeatability.
Note 3: Frequency Range includes a 1% guard band surrounding the User Bands between 30 MHz and 240 MHz.
Note 4: If testing a category "AX with BM" component or subsystem (i.e., PWM DC brush-commutated motors), compliance to the spark requirements as shown in this table requires that the component or subsystem be configured for 100% duty cycle (unless otherwise specified in the test plan) **and** with an actual BM load (e.g., not an R-L-C equivalent). Because the motor load cannot have any significant capacitance installed when using a high-current PWM feed, the BM motor performance can only be assessed when tested as a subsystem with the AX controller.

3.3.1.4 Report. The report must include individual plots for each antenna polarization and test mode. Individual DUT orientation data must also be provided – it is acceptable to provide all orientations on the same plot or individual plots of each (for a given antenna polarization and test mode).

The report must include a tabular listing that clearly identifies, for each band, the Band ID, Region, RF Service Name, Frequency Range, and maximum level (in dBµV/m).

The test report shall also include a summary plot including the highest emission measurements from all polarizations, DUT orientations per test mode.

The scaling of the summary plot should include all frequencies for all bands. The individual plots may be scaled based on the band(s) measured during the particular test run.

3.3.2 CE, Artificial Network (AN). All DUT B+ and switched B+ shall be commonly connected to the output of the artificial network.

3.3.2.1 Equipment. The test equipment shall comply with the requirements of IEC CISPR 25.

Note: As a deviation from IEC CISPR 25 for a remotely-grounded DUT, the simulator/load box shall rest on an insulation support above the ground plane. The insulation support shall have same thickness and other characteristics as that specified for the DUT by IEC CISPR 25. In accordance with IEC CISPR 25, the simulator shall be powered via the artificial networks.

Note: The harness length is permitted to be (1700 +300/-0) mm for both the power lines as well as other I/O. The restriction of IEC CISPR 25 to (200 ± 10) mm for the power lines does not apply, given that this procedure is restricted to the AM broadcast frequency band, where even a 2 m harness is considered electrically-short and does not add significant capacitive filtering to the DUT emissions.

Preamplifier/Preselector: Due to the extremely low level signals that must be observed, a preamplifier (or preselector) may be required ahead of the receiver to improve the system sensitivity.

No DUT I/O filtering or power supply filtering shall be permitted within the simulator, except as provided for the intended load interface definition for the DUT (as detailed in the GMW3103 EMC Test Plan).

3.3.2.2 Procedure. With the 50 Ω termination on the AN that is not being used to measure the CE, connect the receiver to the AN that is being used and record the data. Repeat this for the other power or ground lead of the DUT.

3.3.2.3 Requirements. The voltage level of the conducted emissions shall not exceed the levels of Table 7 and Table 8. The limits apply for artificial networks without correction factors applied.

Table 7: Conducted Emissions Artificial Network (AN) Non-Spark Requirements

ID Number	Region	RF Service	Frequency Range (MHz)	Conditions	Non-Spark Limit (dBµV)	Note
G1	Global	Medium Wave /AM	0.53 to 1.71	RBW 9/10 kHz, Step Size ≤ 5 kHz, Time/Step > 5 ms	42 PK (36 AV)	1

Note 1: The AV (average) detector limit applies only when testing a category "AX with BM" subsystem (i.e., PWM DC brush-commutated motors). The average detector is necessary as a result of the lack of filtering capacitance in the motor (in order to avoid large inrush currents during the PWM operation). Compliance to this AV detector limit requires that the component or subsystem be configured for a nominal 60% duty cycle (unless otherwise specified in the test plan) **and** with an actual BM load (e.g., not an R-L-C equivalent).

Table 8: Conducted Emissions Artificial Network (AN) Spark Requirements

ID Number	Region	RF Service	Frequency Range (MHz)	Conditions	Spark Limit Limit (dBµV)	Note
G1	Global	Medium Wave /AM	0.53 to 1.71	RBW 9 kHz, Step Size ≤ 50 kHz, Time/Step = 1 s	82 QP	1, 2, 3

Note 1: Door lock motors and trunk actuators (which typically are energized for less than 1 second and activated by the driver/occupant) are exempt from the conducted emissions requirements. Starter motors, as a specific device, are also included in this exemption.
Note 2: For QP measurements, the Time/Step may be greater than 1 second to increase repeatability.
Note 3: If testing a category "AX with BM" component or subsystem (i.e., PWM DC brush-commutated motors), compliance to the spark requirements as shown in this table requires that the component or subsystem be configured for 100% duty cycle (unless otherwise specified in the test plan) **and** with an actual BM load (e.g., not an R-L-C equivalent). Because the motor load cannot have any significant capacitance installed when using a high-current PWM feed, the BM motor performance can only be assessed when tested as a subsystem with the AX controller.

3.3.2.4 Report. The test report shall include all plots.

3.3.3 Magnetic Fields (PEPS LF). This requirement is designed to limit the potential interference to the low-frequency (LF, nominally 125 kHz) aspect of the PEPS subsystem from electrical/electronic products (with their typical switching power supplies or PWM load controls). This requirement applies only to those modules or components which both:

a. Are located in the passenger compartment and that can be placed in the immediate proximity of cupholders, storage compartments, glove box, etc., where key fobs for the PEPS system could be placed by the driver and
b. Do not use a full metallic enclosure.

This requirement would not be applicable to, for instance, engine controllers, transmissions controllers, fuel pump control modules, etc.

3.3.3.1 Equipment. The following test equipment is necessary for performing this test.

- All necessary power supply and load simulation to place the DUT in a worst-case switching current operating mode.
- A physically-small (30 mm or less in diameter for a circular probe, or for any side of a square/rectangular probe) commercially-available near-field magnetic field probe (e.g., Beehive Electronics Model 100C).
- An RF spectrum analyzer or receiver (run in the spectrum analyzer mode) capable of measuring 100 kHz to 150 kHz.

Note: A low-noise preamplifier may be necessary, depending upon the noise floor of the measuring equipment.

3.3.3.2 Procedure.

- Spectrum analyzer settings:
- Measurement bandwidth of 3 kHz or less.
- Maximum sweep time of 100 ms or less.
- Peak Detector (in a MAX HOLD mode).

  Note: If a stepped receiver is used, the maximum step size (one-half the measurement bandwidth, maximum) and measurement time (5 ms, typical) combine to yield a significantly longer measurement time prior to any probe movement. Because of this, use of the receiver in this mode (as opposed to the spectrum analyzer mode that most commercially available receivers are capable of) is not recommended.
- For each face of the DUT,
- Orient the face of the probe in along the x-axis as shown in Figure 2.
- With the probe directly on the surface of the DUT, slowly scan/step the magnetic field probe across the surface of the DUT as the receiver/spectrum analyzer steps/sweeps in a PEAK MAX HOLD mode.
- Without clearing the data from the receiver/spectrum analyzer, repeat the scan/step for the remaining two orientations of the probe Peak Detector (in a MAX HOLD mode).
- Repeat for all of the other remaining faces of the DUT.

Convert the measured data to units of dB relative to 1 microtesla, (dBµT), using the appropriate conversion factor for the probe.

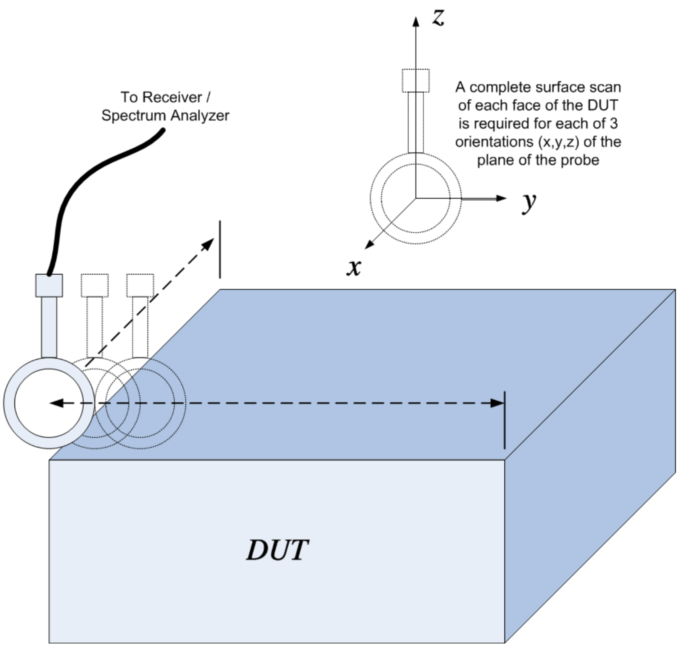


Figure 2: Simplified Scan Orientations for Magnetic Field Measurement

Note: It is recommended that a fast pre-screen be performed in order to identify the location of the highest magnetic field source. To accomplish this, a larger measurement bandwidth may be used (10 kHz or larger) in order to use a faster sweep rate/measurement time. Once the sources of the highest emissions are found (for each probe orientation) across all faces of the DUT, the actual measurements with the reduced measurement bandwidth may be focused on these areas of the DUT. In this case, a complete scan of each face of the DUT with the smaller bandwidth would not be required.

3.3.3.3 Requirements. The maximum magnetic field emissions shall not exceed the levels of Figure 3.

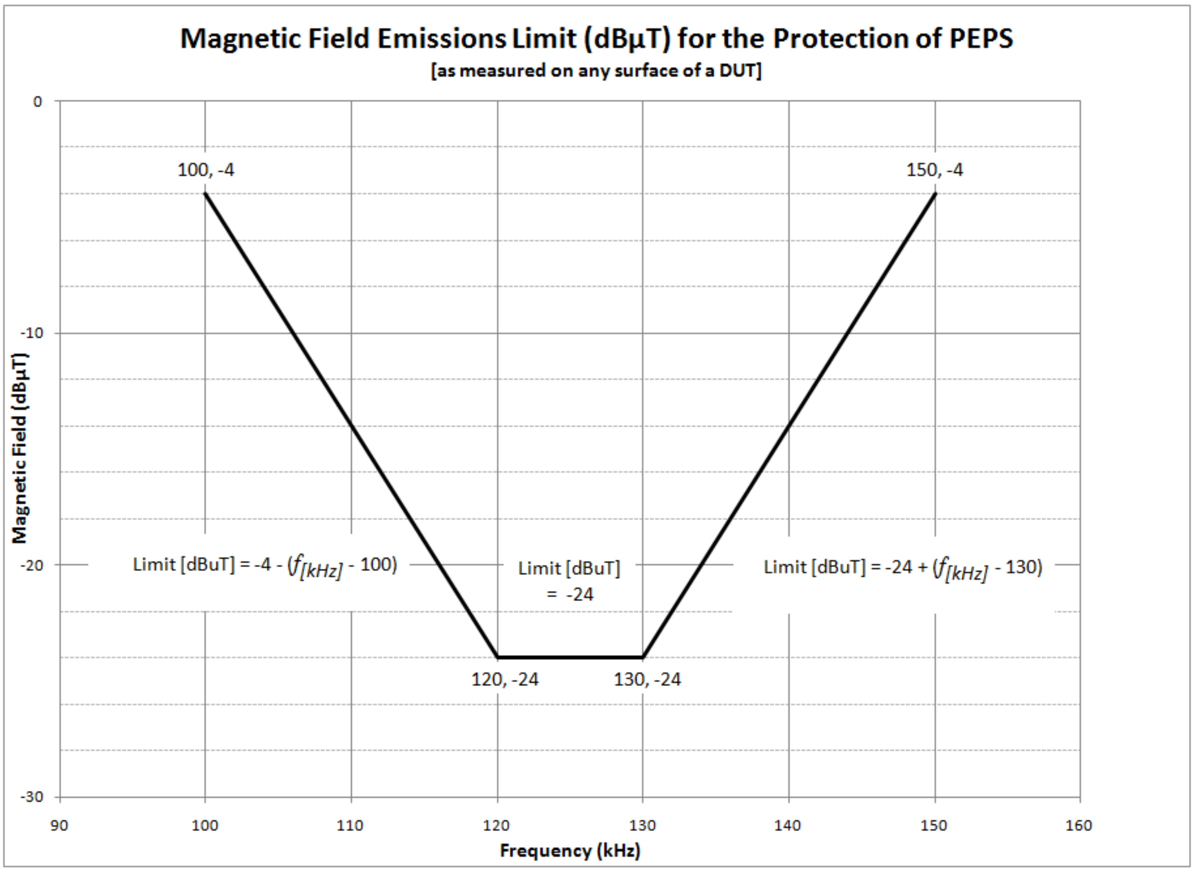


Figure 3: Maximum Magnetic Field Emissions (for the protection of PEPS)

3.3.3.4 Report. The report shall contain a plot of the final MAX PEAK HOLD scan for all probe orientations and DUT faces.

3.4 Radiated Immunity (RI). For all tests the more stringent requirement applies at frequency breakpoints.

When applying RF energy, the following steps shall be satisfied for each frequency step:

- The initial power shall be a minimum of 6 dB below the Level 1 substitution target level.
- **Note:** If deviation(s) were detected at the prior test frequency, it is recommended to use an initial power level that is 6 dB lower than the deviation(s) power threshold.
- The RF level shall be incremented up to the Level 2 substitution targets with minimal overshoot.
- Once the Level 2 target power level is achieved, RF shall be turned off (typically by commanding the RF generator to a -100 dB or lower power level).
- The Level 2 RF level shall be re-applied by commanding the RF generator to the target value. This creates an RF OFF-to-ON transition.
- Dwell with RF on for a minimum of 2 seconds, unless otherwise specified in the test plan.
- Turn RF OFF, typically by commanding the RF generator to a -100 dBm or lower power level.

If any deviations are noted, the determination of deviation (anomaly) thresholds (for each deviation type noted) shall be accomplished as follows:

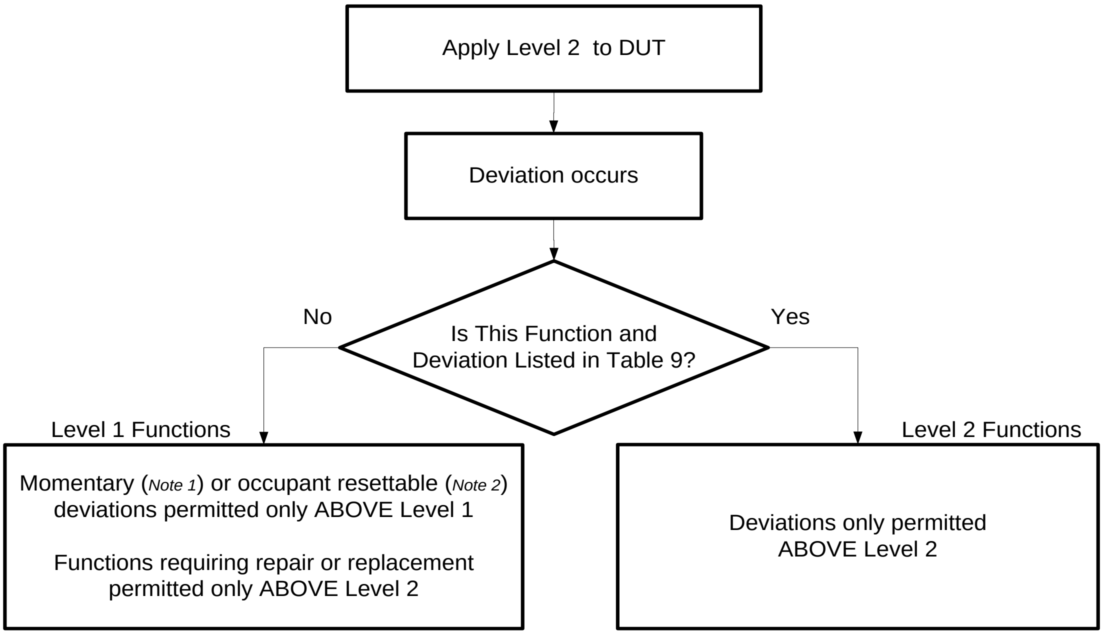
- RF level shall be lowered until the anomaly, or deviation, disappears,
- RF level shall be incremented, by steps not exceeding 1 dB, until the anomaly, or deviation, reappears.

This last level is defined as the anomaly (or deviation) threshold.

A separate deviation threshold plot is required for each deviation type observed during the test.

Note: 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 a deviation occurs during immunity tests, the deviation will be assessed according to Figure 4.



Note 1: Momentary defined to be typically less than one second as approximated by the test operator.

Note 2: Occupant resettable is defined as a reset that can be easily performed from within the vehicle passenger compartment by operation of a DUT control that is intuitive to the occupant, excluding cycling of the vehicle ignition, fuse removal/replacement, or disconnecting the battery cable or DUT power source.

Figure 4: Performance Criteria for Radiated Immunity

Table 9: Immunity Related Functions

a. Functions related to the direct control of the vehicle:
- By degradation or change in: e.g., engine, gear, brake, suspension, steering, speed limitation devices.
- By affecting drivers position: e.g., seat or steering wheel positioning.
- By affecting drivers visibility: e.g., dipped beam, windscreen wiper.

b. Functions related to driver, passenger and other road users protection (e.g., airbag and safety restraint systems).

c. Functions which when disturbed cause confusion to the driver or other road users:
- Optical disturbances: incorrect operation of e.g., direction indicators, stop lamps, end outline marker lamps, rear position lamp, light bars for emergency system, wrong information from warning indicators, lamps or displays which might be observed in the direct view of the driver.
- Acoustical disturbances: incorrect operation of e.g., anti-theft alarm, horn.

d. Functions related to vehicle data bus functionality:
- By degradation, e.g., creating bus error frames, error codes, or blocking data transmission on vehicle data bus-systems which are used to transmit data required to ensure other immunity related functions.

e. Functions which when disturbed affect vehicle statutory data (e.g., tachograph, odometer).

The Anechoic Chamber Test and the Reverberation Chamber Test are currently considered to be equivalent. With the exception for DUTs which contain an RF receiver as part of their design (e.g., infotainment radio, Remote Frequency Actuation (RFA)/Remote Keyless Entry (RKE) Receiver, etc.), either of the following test methods may be used: Paragraph 3.4.2 - Anechoic Chamber Test, or Paragraph 3.4.3 - Reverberation Chamber Test, Mode Tuning. Mode Tuning is disallowed for validating DUTs with receivers.

- DUT Monitoring Instrumentation: Instrumentation and/or observation is/are used to monitor the parameters of the DUT in order to determine its performance during the test. The monitoring instrumentation and technique shall be documented in the test report. Monitoring of particular DUT functions must not disturb its operation or couple in any extraneous RF energy that it would not normally experience.
- Electrically monitored signals and input signals shall be connected using high impedance (10 × the impedance of the signal, 10 kΩ minimum) connections to avoid coupling to the chamber wall.
- The use of fiber optic-based monitoring is preferred. The fiber optic equipment, if externally powered, shall be powered from a separate battery from that supplying the DUT and load box.
- All equipment used for monitoring (such as fiber-optics, etc.) shall be electrically isolated from the ground plane.
- Any/all monitoring, including sampling of signals in an automated test configuration, shall include monitoring during the RF ON/OFF transitions required at each test frequency, as well as during the RF dwell required at each test frequency.
- DUT Load Box: The load box/simulator shall be located within the test chamber. For the case of a remotely-grounded DUT, it shall be electrically isolated from the ground plane (e.g., located on the DUT-side of the artificial network on the battery negative feed).
- DUT I/O Cycling: During RF transitions as well as RF dwell times, all I/O of a DUT (including operator interfaces, such as switches, touch-screens, etc.) shall be exercised according to Appendix A. Details shall be documented in the GMW3103 EMC test plan.

The following equation shall be used for the frequency ranges in Table 10 for the following tests:

- Bulk Current Injection, 3.4.1.
- Anechoic Chamber Test, 3.4.2.
- Reverberation Chamber Test, Mode Tuning, 3.4.3.

$$f_{test} = f_0 \cdot 2^{\left(\frac{k}{n}\right)}$$

Where:

f_0 Base frequency

k Frequency index number (0, 1, 2)

n Number of steps per octave

Table 10: Test Frequency Calculation

Frequency Range (MHz)	f_0 (MHz)	n
1 to < 30	1	7
30 to < 400	30	25
400 to < 1000	400	25
1000 to 2000	1000	50

Note: Frequencies are to be rounded to at least 4 significant digits.

3.4.1 RI, Bulk Current Injection (BCI).

3.4.1.1 Equipment. The test equipment shall comply with ISO 11452-1 and ISO 11452-4.

3.4.1.2 Procedure. Use test methods according to the relevant sections of ISO 11452-1 and ISO 11452-4 with the following exceptions:

- Use test frequencies specified in Table 10.
- All modulation dwell times (i.e., time that RF is applied for per modulation type) shall be at least 2 s (unless otherwise specified in the EMC Test Plan). Use calibrated injection probe method (substitution method) according to ISO 11452-4.
- In the frequency range 1 MHz to 30 MHz, ground wires that are power returns (for B+ and/or IGN), as well as reference returns for reference voltages supplied by electronic modules (i.e., 5 V returns, etc.) directly or indirectly (through load box/simulator) shall be routed outside of the injection probe; this is called Differential-Mode BCI (DBCI).
- In the frequency range 30 MHz to 400 MHz, all wires of the DUT wiring harness shall be routed inside of the injection probe. This is called Common-Mode BCI (CBCI).
- For those devices, such as alternators, etc., that use ONLY a case ground and, as a result, do not have a ground return lead, or for those 2-leaded sensors that do not employ a ground reference, the concept of DBCI and CBCI is confusing. As such, when testing these devices, the CBCI setup (e.g., all DUT wires routed inside the injection probe) shall be used.
- Three fixed injection probe positions are defined (150 mm, 450 mm, and 750 mm).
- Use only **150 mm** and **450 mm** injection probe positions when testing between 1 MHz to 30 MHz (i.e., when performing **DBCI**).
- Use only **450 mm** and **750 mm injection probe** positions when testing above 30 MHz (i.e., when performing **CBCI**).
- All (3) probe positions, 150 mm, 450 mm, and 750 mm, shall be used when testing from 1 MHz to 400 MHz for those devices, such as alternators, which have no ground return lead and use case ground only, or those 2-leaded sensors that do not directly employ a ground reference.
- Use wiring harness length of (1700 +300/-0) mm.

Note: For this test, if a laboratory is unable to have the full length of the harness straight along the edge of the table, the harness shall be kept straight for a length of 1500 mm, minimum, from the DUT. The remaining wire length to the simulator and/or artificial networks shall not be coiled and shall be spaced at least 5 cm from the chamber walls and the edge of the ground plane.

- The negative lead of the power supply for the DUT shall be attached to the ground plane with a low RF impedance connection.
- If the outer case of the DUT can be grounded when installed in the vehicle, the DUT must be mounted and electrically connected to the ground plane during the bench test. If the DUT case is not grounded in the vehicle, the DUT shall be placed on an insulated support such that the closest part of the DUT circuit board is positioned (50 ± 5) mm above the ground plane during the bench test. The DUT position/orientation shall be documented in the test report.
- The injection probe shall be insulated from the ground plane.
- For calibration and during the actual test of a DUT forward power shall be used as reference parameter.
- An appropriate current monitoring probe which does not affect the deviation profile may be placed 5 cm from the DUT (optional).

Note: Caution. For high current devices, a physically large injection probe may influence the operation of the device.

3.4.1.3 Requirements. DUT functions may only deviate above the levels specified in Table 11 and Figure 5.

Table 11: Requirement Levels for the Immunity to Electromagnetic Fields for Components and Subsystems Measured Using the CBCI and DBCI Method

Frequency Range (MHz)	Level 1 (dBµA)	Level 2 (dBµA)	Method	Modulation Note 1
1 to 15	64 to 100	70 to 106	DBCI Note 2	CW, AM 80%
15 to 30	100	106	DBCI Note 2	CW, AM 80%
30 to 400	100 to 89	106 to 95	CBCI	CW, AM 80%

Note 1: For intentional AM receivers, audio deviations due to AM 80% modulation may be disregarded.
Note 2: For those devices, such as alternators, etc., that use ONLY a case ground and, as a result, do not have a ground return lead, or for those 2-leaded sensors that do not employ a ground reference, the CBCI setup (e.g., all DUT wires routed inside the injection probe) shall be used.

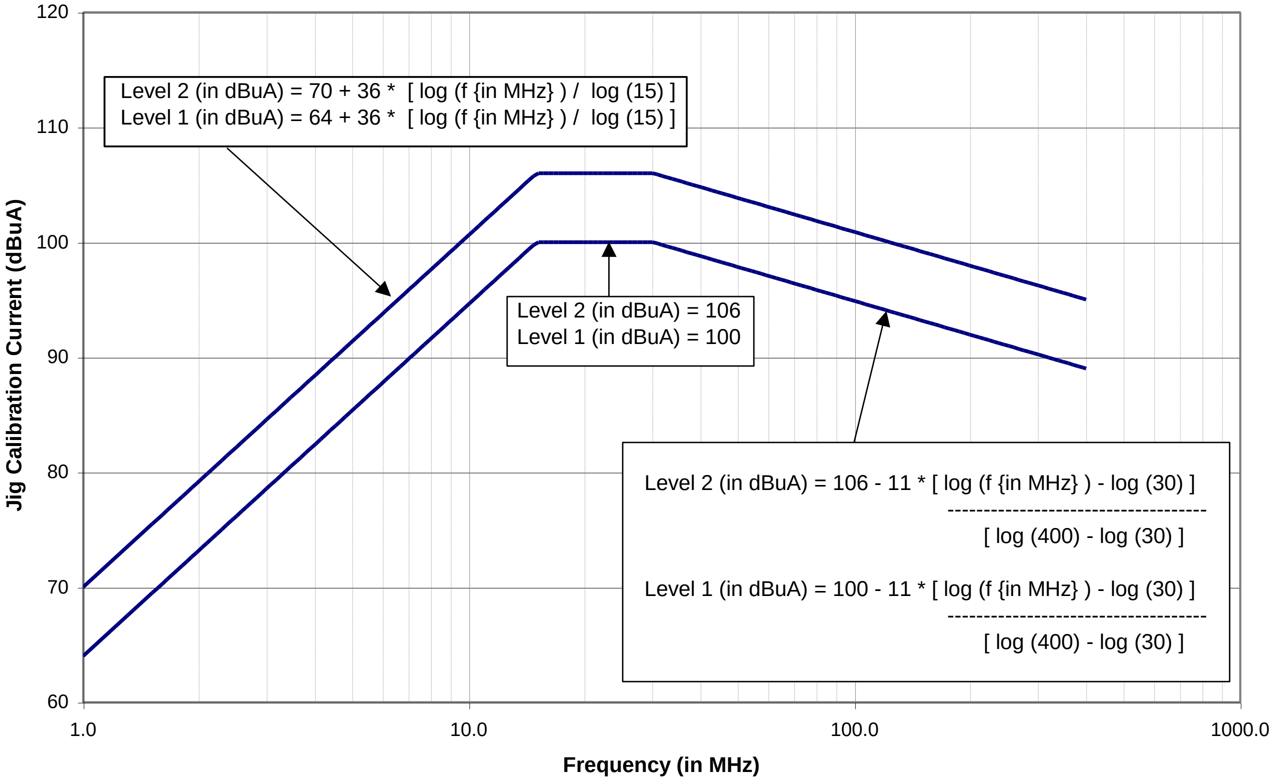


Figure 5: Requirement Levels for the Immunity to Electromagnetic Fields for Components and Subsystems Measured Using the CBCI and DBCI Method

3.4.1.4 Report. The following elements shall be included in the test report:

- Description of the functions monitored.
- Any performance deviations.
- Modulation Status.
- RF Dwell Time.
- Equipment limit indication.
- Immunity threshold Data.
- Both tabular data and plots (showing stress levels, including maximum exposure levels, and thresholds versus frequency **for each deviation title**) for each of the 3 probe positions.

- Combined tabular data and plots to form a single worst-case data set for each deviation.
- Test level requirements (e.g., Level 1 and Level 2) included on all plots.
- Any exposure levels limited by equipment limitations shall also be identified.

Note: At each frequency, the probe position with the lowest deviation threshold is chosen for the combined data set.

- Monitoring instrumentation and technique.

3.4.2 RI, Anechoic Chamber.

3.4.2.1 Equipment. The test equipment shall comply with ISO 11452-1 and ISO 11452-2 from 400 MHz to 2 GHz with the following specifications:

- The substitution method shall be used.
- In the frequency range 400 MHz to 1 GHz the field-generating device (antenna) shall be oriented as described in ISO 11452-2.
- For the frequency range 1 GHz to 2 GHz, the field-generating device (antenna) shall be moved 0.75 m parallel to the front edge of the ground plane towards the DUT.
- During calibration, the measuring device (field probe or antenna) shall also be moved 0.75 m parallel to the front edge of the ground plane.
- For the frequency range of 1.2 GHz to 1.4 GHz (e.g., pulsed radar bands), refer to Appendix B for clarification of calibration methods.
- Horizontal and vertical polarization shall be used.
- The DUT shall be tested in a minimum of three orientations (unless otherwise specified in the EMC Test Plan).
- For calibration and during the actual test of a DUT, forward power shall be used as reference parameter.

3.4.2.2 Procedure. The test procedure shall comply with ISO 11452-2 from 400 MHz to 2 GHz with the following specifications:

- Use test frequencies specified in Table 10.
- The load box /simulator shall be located within the test chamber.
- All modulation dwell times (i.e., time that RF is applied per modulation type) shall be at least 2 s (unless otherwise specified in the EMC Test Plan).

3.4.2.3 Requirements. DUT functions may only deviate above the levels specified in Table 12.

Table 12: Requirement Levels for the Immunity to Electromagnetic Fields for Components and Subsystems Measured in the Anechoic Chamber

Frequency (MHz)	Level 1 (V/m)	Level 2 (V/m)	Modulation
400 to 800	50	100	CW, AM 80%
800 to 1000	50	100	CW, AM 80%
800 to 1000	50	70	PM PRR = 217 Hz, PD = 0.57 ms Note 3
1000 to 2000	50	70	CW, PM PRR = 217 Hz, PD = 0.57 ms Note 3
1200 to 1400	Note 1	600 Note 2, Note 3, Note 4	Radar pulse packets (PRR = 300 Hz, PD = 6 µs), with only 50 pulses output every 1 s

Note 1: For Level 1 functions, only momentary (less than 1 second, typical), self-resettable deviations are allowed up to and including 600 V/m. Occupant-resettable deviations are NOT ALLOWED for this test for Level 1 functions.
Note 2: No deviations are permitted at or below 600 V/m for Level 2 functions.
Note 3: Pulsed field strength requirements are peak V/m (maximum RMS) levels.
Note 4: Refer to Appendix B for allowable calibration methods for this radar test band.

3.4.2.4 Report. The following elements shall be included in the test report:

- Description of the functions monitored.
- Any performance deviations.
- Modulation status.
- Immunity threshold data.
- A single worst-case plot (for each deviation), showing stress levels, including maximum exposure levels, and thresholds versus frequency.
- Test level requirements (e.g., Level 1 and Level 2) included on all plots.
- Any exposure levels limited by equipment limitations shall also be identified.
- Monitoring instrumentation and technique.

3.4.3 RI, Reverberation Chamber, Mode Tuning.

Note: This method is not permitted for DUTs that contain an RF receiver as part of their design (e.g., infotainment radio, RFA/RKE Receiver, etc.)

3.4.3.1 Equipment.

- Reverberation chamber: Sized large enough to test a DUT within the working volume of the chamber.
- Mechanical tuner: As large as possible with respect to overall chamber size (at least three-quarters of the smallest chamber dimension) and working volume considerations. In addition, each tuner should be shaped such that a non-repetitive field pattern is obtained over one revolution of the tuner.
- Electric field probes: Capable of reading and reporting three orthogonal axes.

  Note: For the frequency range 1.2 GHz to 1.4 GHz (e.g., pulsed radar band), it may be necessary to use peak power sensors to measure the field strength during calibration and test. Calibrating via CW mode with the DUT present is not acceptable.
- RF Signal Generator: Capable of covering the frequency bands and modulations specified.
- Transmit antenna: Linearly polarized antenna capable of satisfying frequency requirements. The transmit antenna shall not directly illuminate of the test volume.
- Receive antenna: Linearly polarized antenna capable of satisfying frequency requirements. The receive antenna shall not be directed into the test volume.
- Power amplifiers: Capable of amplifying the RF signal to produce the required field strengths.
- Associated equipment to record the power levels necessary for the required field strength.

3.4.3.2 Procedure.

- Use test frequencies as specified in Table 10.
- The test set up is specified in IEC 61000-4-21.
- All modulation dwell time (i.e., time that RF is applied for per modulation type) shall be at least 2 s.
- Electric field probes shall not be used during the test.
- Ground planes shall not be used in this test.
- For DUTs that have no power return wire, a ground strap no wider than 13 mm may be used to connect the DUT to the battery.
- The DUT shall be at least 0.25 m from the chamber walls, tuner, transmit antenna, and receive antenna.
- The test chamber must have been calibrated according to IEC 61000-4-21, with the exception that Table 13 be used to replace Table B1, Sampling Requirements, of IEC 61000-4-21 A.1 (Chamber Calibration and Loading Validation).
- The transmit antenna shall be in the same location as used for calibration.
- A (1700 +300/-0) mm harness shall be used unless otherwise specified in the test plan.
- The DUT shall be exposed to each field level and frequency at each mode tuner position.

Table 13: Independent Samples and Frequencies

Frequency Range (MHz)	Number of Samples (i.e., independent tuner positions or intervals) Recommended for Calibration and Test	Number of Frequencies (logarithmically spaced) Required for Calibration
400 to 1000	12	20
1000 to 2000	6	15

3.4.3.3 Requirements. DUT functions may only deviate above the levels specified in Table 14.

Table 14: Requirement Levels for the Immunity to Electromagnetic Fields for Components and Subsystems Measured in the Reverberation Chamber

Frequency (MHz)	Level 1 (V/m)	Level 2 (V/m)	Modulation
400 to 800	50	100	CW, AM 80%
800 to 1000	50	100	CW, AM 80%
800 to 1000	50	70	PM PRR = 217 Hz, PD = 0.57 ms Note 3
1000 to 2000	50	70	CW, PM PRR = 217 Hz, PD = 0.57 ms Note 3
1200 to 1400	Note 1	600 Note 2, Note 3	Radar pulse packets (PRR = 300 Hz, PD = 6 µs), with only 50 pulses output every 1 s

Note 1: For Level 1 functions, only momentary (less than 1 second, typical), self-resettable deviations are allowed up to and including 600 V/m. Occupant-resettable deviations are NOT ALLOWED for this test for Level 1 functions.
Note 2: Deviations are only permitted above 600 V/m for Level 2 functions.
Note 3: Pulsed field strength requirements are peak V/m (maximum RMS) levels.

3.4.3.4 Report. The following elements shall be included in the test report:

- Description of the functions monitored.
- Any performance deviations.
- Modulation status.
- Immunity threshold Data.
- A single worst-case plot (for each deviation), showing stress levels, including maximum exposure levels, and thresholds versus frequency.
- Test level requirements (e.g., Level 1 and Level 2) included on all plots.
- Any exposure levels limited by equipment limitations shall also be identified.
- Number of tuner steps at each frequency.
- Monitoring instrumentation and technique.

3.4.4 Immunity to Power Line Magnetic Fields.

3.4.4.1 Equipment. The test equipment shall comply with ISO 11452-8, using the Helmholtz coil method with the following exceptions:

- Testing shall be performed using the discrete frequencies as detailed in Table 15.
- Sine wave generator shall be used.

3.4.4.2 Procedure Use test methods according to ISO 11452-8 with the following specifications:

- Use the RMS current through the magnetic coils as the reference parameter for calibration and test.
- At each field intensity level expose the DUT for a minimum of 30 s.

- Use the test frequencies and waveforms according to Table 15. Additional frequencies may be required per the GM EMC Engineer and which shall be defined in the test plan.
- The use of one or two amplifiers is allowed.
- Test three orthogonal DUT orientations.

  Note: Additional orientations and/or positions may be required for some magnetic field-based sensors, such as Hall-Effect sensors. These additions shall be defined by the GM EMC Engineer and documented in the EMC Test Plan per GMW3103.
- The harness shall be routed to the load simulator parallel to the face (plane) of the coil.

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

3.4.4.3 Requirements. DUT functions may only deviate above the levels specified in Table 15. These requirements are considered Level 2. As such, no deviations are permitted below this exposure level for both Level 1 and Level 2 functions.

Note: Increased magnetic field levels may be required for some magnetic field-based sensors, such as Hall-Effect sensors. These increased levels shall be defined by the GM EMC Engineer and documented in the EMC Test Plan per GMW3103.

Table 15: Magnetic Field Immunity Requirements

Frequency (Hz)	Requirement (µT RMS)	Signal Generator Voltage Output Waveform
16 2/3	50	Sine Wave
50		
60		
150	25	
180		

3.4.4.4 Report. The following elements shall be included in the test report:

- Description of the functions monitored.
- Any performance deviations.
- Maximum exposure field at each frequency.
- Equipment limit indication.
- The requirement shall also be included with the deviation threshold.

3.5 Transient, Conducted Emissions (CE) and Conducted Immunity (CI). During Conducted Immunity testing, each DUT function (including diagnostic codes) whose immunity may vary according to its internal timing or processing functions should be considered in the test plan. The time allowed between the pulses, the number of pulses and the pulse voltage levels applied should maximize the probability that a test pulse is applied during times of highest DUT susceptiblity. These variations shall be noted within the GMW3103 EMC Test Plan.

Note: CE and CI is assessed at room temperature unless otherwise specified in the test plan. However, because of temperature sensitivity of some capacitors (e.g., electrolytic capacitors may lose up to 50% of their capacitance at extreme low temperatures and, thus, a reduction in their filtering capability), the part must be designed for cold temperature extremes dictated by the individual component technical specifications. Additionally, semiconductors may be more vulnerable at elevated temperatures and, as such, may require testing at elevated temperatures. Any special at-temperature testing requirements for transients shall be detailed in the EMC test plan and report.

3.5.1 CE, Transients.

3.5.1.1 Equipment. The test equipment shall comply with ISO 7637-1 and ISO 7637-2, with the exception of the supply voltage as detailed in 3.1.2.

3.5.1.2 Procedure. Use test methods in accordance with ISO 7637-2 with the following specifications:

- The shunt resistor R_s as shown in Figure 1b of ISO 7637-2 shall not be installed.

  Note: For ease of understanding, this figure is reproduced as Figure 6.

- Ensure that the 50 Ω termination is installed on the RF sampling port of the AN.

Motors and actuators that can stall during normal operation shall, in addition to the off-to-on and on-to-off modes, be tested in a “stall” condition. The stall should not be held longer than one second. This is to prevent activation of in-line protection devices (such as Positive-Temperature Coefficient (PTC) resistors) that would interrupt current to the DUT.

3.5.1.3 Requirements. The voltage levels of Conducted Transients shall not exceed the levels of Table 16 when the DUT is evaluated in accordance with ISO 7637-2.

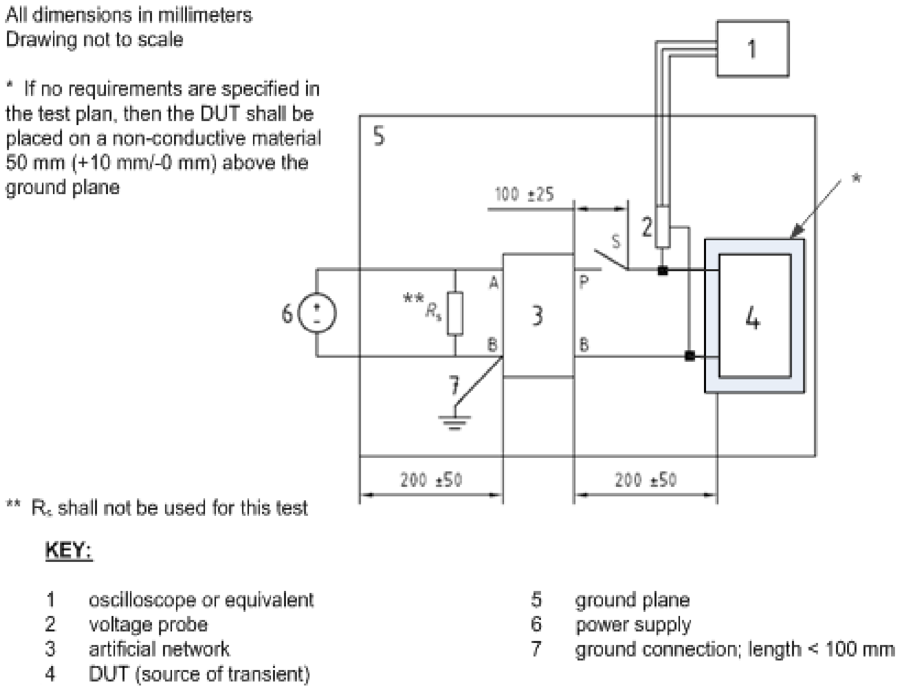


Figure 6: ISO 7637-2 Reference Diagram (1b) for CE Transient Measurements

Table 16: Limits for Conducted Transients

<table>
<tr><th rowspan="2">Test Method</th><th rowspan="2">Measurement Location</th><th rowspan="2">Device Category</th><th colspan="2">Limits</th><th rowspan="2">Notes</th></tr>
<tr><th>Maximum (V)</th><th>Minimum (V)</th></tr>
<tr><td rowspan="4">Per ISO 7637-2, Figure 1b</td><td rowspan="2">Measured directly across the inductive load terminals</td><td>BM</td><td>+200</td><td>-400</td><td></td></tr>
<tr><td>R</td><td>+100</td><td>-150</td><td>If the relay incorporates a physical resistor (across the relay coil) whose value is limited to ten times (10×) the resistance of the coil, this requirement can be validated by inspection</td></tr>
<tr><td rowspan="2">Measured at Point ‘P’ referenced to ‘B’</td><td>BM</td><td>+100</td><td>-200</td><td></td></tr>
<tr><td>R</td><td colspan="3">Not Applicable</td></tr>
</table>

3.5.1.4 Report. The following elements shall be included in the test report:

- Plots of all measured pulses.
- Description of DUT conditions.
- Appropriate requirement shall be displayed on plot of pulses.

Note: Consistent with ISO 7637-2, (unless otherwise specified in the EMC Test Plan), 10 waveform acquisitions are required for each mode of operation (e.g., ON-to-OFF, OFF-to-ON, etc., as specified in the EMC Test Plan). Only those waveforms with the highest positive and negative amplitudes shall be reported.

3.5.2 CI, Transients on Power Lines.

3.5.2.1 Equipment. The test equipment shall comply with ISO 7637-1 and ISO 7637-2, with the exception of the power supply as detailed in 3.1.2.

Instrumentation according to the test plan shall be used to monitor the parameters of the DUT.

The monitoring instrumentation shall not disturb DUT operation or alter its immunity to the injected pulse(s).

Note: Some devices, such as engine and transmission-mounted sensors, may require transient testing at an elevated operating temperature. Additionally, some devices may require testing during exposure to extreme cold temperatures. In these cases, a thermal chamber will be required. Any/all at-temperature conducted transient immunity testing shall be documented in the test plan.

3.5.2.2 Procedure. If not otherwise stated, this test procedure applies to battery+ (B+) and switched battery lines (e.g., Ignition, Accessory). It also applies to I/O lines that are connected to an inductive load, where that load is fed by B+ or switched battery.

The test pulses shall be applied to B+, each switched battery line and I/O lines fed by either B+ or switched battery separately.

In addition, B+ and switched battery lines and I/O lines fed by either B+ or switched battery shall be tested simultaneously.

Use test methods according to the relevant sections of ISO 7637-2 with the following specifications and/or exceptions:

- The point of injection for all pulses shall be 50 mm (maximum) from the connector pins of the DUT. The standard (1700 +300/-0) mm harness may be used, with these injection locations available for test.
- For all injections, the reference for the transient pulse generator (e.g., the "**-**" lead) shall be connected to the DUT ground wire (within 50 mm, maximum, of the DUT connector pin(s)).
- The harness shall be located a minimum of 5 cm above a ground plane for all pulses, unless otherwise specified in the test plan.

- The DUT shall be placed on a non-conductive material a minimum of 5 cm above the ground plane, unless otherwise specified in the test plan.
- Perform the test using pulses 1, 2a, 3a, 3b, and 4, in accordance with ISO 7637-2.

  Note: Due to the vehicle build process, Pulse 1 is no longer restricted to switched battery lines – it shall be applied to both B+ and switched battery lines, separately and simultaneously.
- The waveform amplitude for pulse 3a and pulse 3b is determined from the average of the waveform peak voltages. For this standard, the injection levels shall be established across a 50 Ω load instead of the open-circuit condition per ISO 7637-2.
- Pulse 4 is only applicable to B+ and switched battery lines which are powered during cranking.

Additionally, test pulses 5b and 7 shall also be performed (as detailed in the sections which follow).

Use Table 19 to determine the number of pulses or test time for pulses 1 thru 7.

Specific for the suppressed load dump (pulse 5b), use the test setup in accordance with ISO 7637-2.

- Use 2 Ω as the source resistance (R_i).
- Do not install the optional resistor which represent the vehicle loading (e.g., R_V per ISO 7637-2).
- Remove the suppression network (e.g., optional diode bridge per ISO 7637-2) and verify that the open circuit unsuppressed load dump voltage waveform meets the specifications of Table 17.
- Connect the suppression network and verify that the open circuit suppressed voltage waveform meets the specifications of Table 17.
- Connect the 2 Ω load and verify that the suppressed loaded open circuit voltage waveform meets the specifications of Table 18.
- Replace the 2 Ω load with the DUT and begin test.

Table 17: Open Circuit Load Dump Pulse Parameters Specifications

Parameter	Unsuppressed	Suppressed
Transient Amplitude	+100 V ± 10%, ($U_a + U_s$)	+34 +0/-1 V, ($U_a + U_{s*}$)
t_d	400 ms ± 30%	400 ms ± 30%
t_r	≤ 10 ms	≤ 10 ms

Table 18: Two Ohm Loaded Load Dump Voltage Pulse Parameter Specifications

Parameter	Suppressed
$U_a + U_s^*$	+34 +0/-1 V

Specific for test pulse 7 (simulation of a wiper motor switching transient), use the test setup in Figure 7 with the following specifications:

- Use ISO pulse 2a with negative polarity.
- The DC supply voltage of the transient generator is switched off during application of the pulse.

The 50 Ω termination shall not be used on the measurement port of the AN.

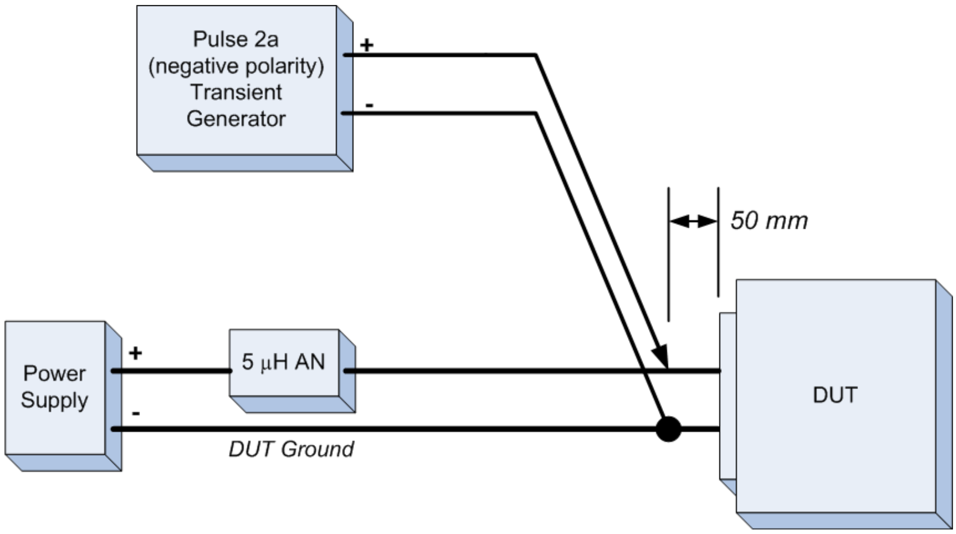


Figure 7: Setup for Pulse 7 (Simulation of Wiper Motor Switching Transient)

3.5.2.3 Requirements. DUT functions may only deviate from the designed performance above the levels according to Table 19 and Table 20 when evaluated according to ISO 7637-2.

Table 19: Requirements Levels for the Immunity to Transients on Power Lines

Pulse Number	Level (V) (open-circuit, unless otherwise specified)	Number of Pulses or Application Time Minimum	Pulse Cycle Time		Acceptance Criteria and Comments
			Minimum (default)	Maximum	
1	U_S = -150	500 pulses	t_1 = 0.5 s Note 1	t1 = 5 s	One or more functions of the DUT can go beyond specified tolerance provided that all functions return within normal limits after the exposure is removed (e.g., after U_A power is re-applied after the 200ms defined by t_2). Memory functions shall perform as designed.
2a	U_A+U_S = +50	500 pulses	t_1 = 0.5 s	t_1 = 5 s	Deviations from intended design performance are only permitted at test levels of higher severity than shown.
3a	U_S= -200	10 minutes	t_5 = 90 ms	t_5 = 110 ms	Deviations from intended design performance are only permitted at test levels of higher severity than shown. Note 2
3b	U_A+U_S= +100	10 minutes	t_5 = 90 ms	t_5 = 110 ms	Deviations from intended design performance are only permitted at test levels of higher severity than shown. Note 2

Pulse Number	Level (V) (open-circuit, unless otherwise specified)	Number of Pulses or Application Time Minimum	Pulse Cycle Time		Acceptance Criteria and Comments
			Minimum (default)	Maximum	
4	See Table 20	1 pulse of each severity level	0.5 s	15 s	Voltage levels and Performance Criterion for Pulse 4 (crank pulse) see Table 20.
5b	$U_A + U_S$ = (34 +0/-1)	10 pulses	15 s	2 minutes	This pulse is not applicable to DUTs used exclusively in Electric Vehicles (EV), or Hybrid Electric Vehicles (HEV) (i.e., where the conventional alternator is not used). In the event the exclusive usage is unknown and/or cannot be guaranteed, Pulse 5b applies. No permanent DUT performance deviations shall be observed after exposure to a load dump pulse with a suppressed open circuit voltage of (34 +0/-1) V, Ri = 2 Ω
7	U_S = -50	500 pulses	t_1 = 0.5 s	t_1 = 5 s	Deviations from intended design performance are only permitted at test levels of higher severity than shown.

Note 1: The minimum time must be long enough for the DUTs return to normal operation.
Note 2: As an exception to ISO 7637-2, the test level shall be set by connecting the generator to a 50 Ω load and the test level established across this load. The 50 Ω load shall then be disconnected before connecting the DUT to the generator.

Table 20: Requirements Levels for the Immunity to Pulse 4: Crank Pulse

Pulse Severity	U_S Note 1	U_a Note 1	t_9 Note 1	t_{11} Note 1	Performance Criterion
I	4 V	2.5 V	1 s	40 ms	One or more functions of the DUT can go beyond specified tolerance as long as all functions automatically return within normal limits after the exposure is removed. Memory functions and functions required to start an engine shall perform as designed.
II	5 V	3 V, 2.5 V	2 s	60 ms	
III	6 V	4 V, 3 V, 2.5 V	5 s	80 ms	
IV	7 V	5 V, 4 V, 3 V, 2.5 V	10 s	100 ms	

$\mathbf{t_{10}}$, $\mathbf{t_8}$ and $\mathbf{t_7}$ as defined in ISO 7637-2. Default value for $\mathbf{t_7}$ shall be 15 ms. Default value for $\mathbf{t_8}$ shall be 50 ms. All severity levels shall be tested.
Note 1: As defined in ISO 7637-2.

3.5.2.4 Report. The following elements shall be included in the test report:

- Test pulse being applied (by number).
- Number of repetitions of the pulse applied.
- Pulse cycle time (interval between pulses).
- Injection points (pin number, letter, or name).
- Performance of the functions monitored during and following application of each transient.

- Transient verification waveforms for each pulse type, complete with clearly stated waveform scales, shall also be included in the test report.

Note: The above information should be formatted into a table. Examples of monitored parameters shall be included in the report.

3.5.3 CI, Coupling to I/O (Other Than Power Supply Lines). The purpose of this test is to ensure conducted transients inductively or capacitively coupled to inputs and outputs (I/O), other than battery, ignition or accessory inputs, do not disturb module functionality and/or memory functions.

3.5.3.1 Equipment. The test equipment shall comply with ISO 7637-1 and ISO 7637-3. An exception to the standards is the power supply voltage as detailed in 3.1.2.

3.5.3.2 Procedure. Use test methods according to the relevant sections of ISO 7637-3 with the following specification:

- Use only test pulse 3a and 3b.

Note: Consistent with ISO 7637-3, coupling clamp method, DUT battery (B+) and, switched battery lines along with DUT supply return (B-) line(s) shall be routed outside the clamp, unless otherwise stated in the test plan.

Note: Direct pin capacitive coupling (DCC) method, as shown in Figure 8, using a 220 pF ceramic capacitor is an alternative to the coupling clamp (refer to 3.5.4 for test setup and procedure only). The requirements of Table 21 apply.

Any functional performance deviations of the DUT shall be recorded in the test report. This also includes functions of the DUT that are unrelated to the specific I/O injection pin, but that could potentially be coupled internal to the DUT via trace routings, sharing of common integrated circuits, etc. Determination of the threshold for any functional deviations is not required for this characterization.

3.5.3.3 Requirements. DUT functions may only deviate at peak levels greater than those shown in Table 21.

3.5.3.4 Report. The following elements shall be included in the test report:

- Test pulse being applied (by number).

Performance of the functions monitored during and following application of each transient.

Table 21: Requirements of Coupling Clamp and (Optional) Direct Pin Capacitive Coupling (DCC)

Pulse Number	Level (Vpeak) Note 1	Application Time	Default Time Between Pulses	(Optional) DCC Coupling Capacitance Note 2
3a	-200	10 minutes	90 ms	220 pF
3b	+200			

Note 1: Test level established across a 50 Ω load terminating the clamp (no harness cables routed through the clamp).
For optional DCC method as an exception to ISO 7637-3, the test level shall be set by connecting the generator to a 50 Ω load and the test level established across this load. The 50 Ω load shall then be disconnected before connecting the DUT to the generator via the coupling capacitor.
Note 2: When performing injections for the DCC method, care must be taken to ensure that the capacitor is not damaged as a result of injection. A capacitor with typical Working Voltage DC (WVDC) of 200 V or more should be used, which provides a safety margin for the momentary transient durations and levels as shown above. Additionally, placing (2) capacitors in series (such that the resultant capacitance is 220 pF ± 10%) can increase the equivalent working voltage of the injection setup.

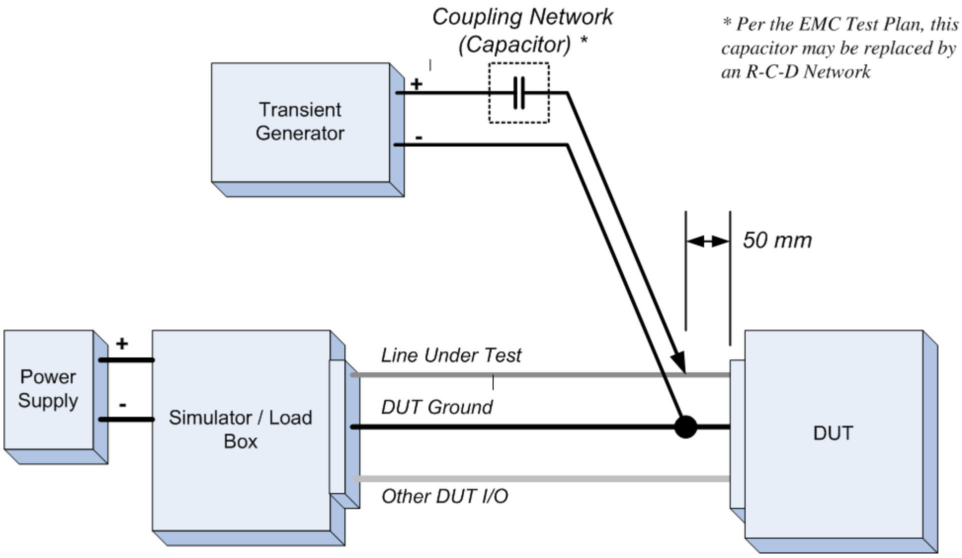


Figure 8: Setup for Direct Capacitor Coupling (DCC)

3.5.4 CI, Direct Capacitor Coupling to Sensor Lines. This test applies to sensors, Category AS devices, (powered from regulated power supplies in other modules).

The purpose of this test is to identify potential sensitivities to transients that may occur as a result of wiring harness coupling (e.g., cross talk). Other inductive coupling methods are being examined and may replace this test in a future revision.

3.5.4.1 Equipment. The test equipment shall comply with ISO 7637-1 and ISO 7637-3, as well as ISO 7637-2 for the definition of Pulse 2a. An exception to the standards is the power supply voltage as detailed in 3.1.2.

3.5.4.2 Procedure. Refer to Figure 8 for a typical setup.

The transient shall be capacitively coupled from generator to the applicable DUT pin by inserting a series ceramic capacitor between the generator (+) output pin and the applicable DUT pins. Additionally, due to possible functional performance issues created by the addition of this capacitor, a discharge circuit (comprised of resistor and/or diodes) may be added per approval by the GM EMC engineer. A typical configuration is shown in Figure 9.

As an exception to ISO 7637-3 for Direct Capacitive Coupling, the generator (-) shall be directly connected to the DUT ground reference for this test instead of the ground plane as defined in the ISO standard.

The injection point shall be within 50 mm of the DUT connector, unless otherwise documented in the EMC Test Plan.

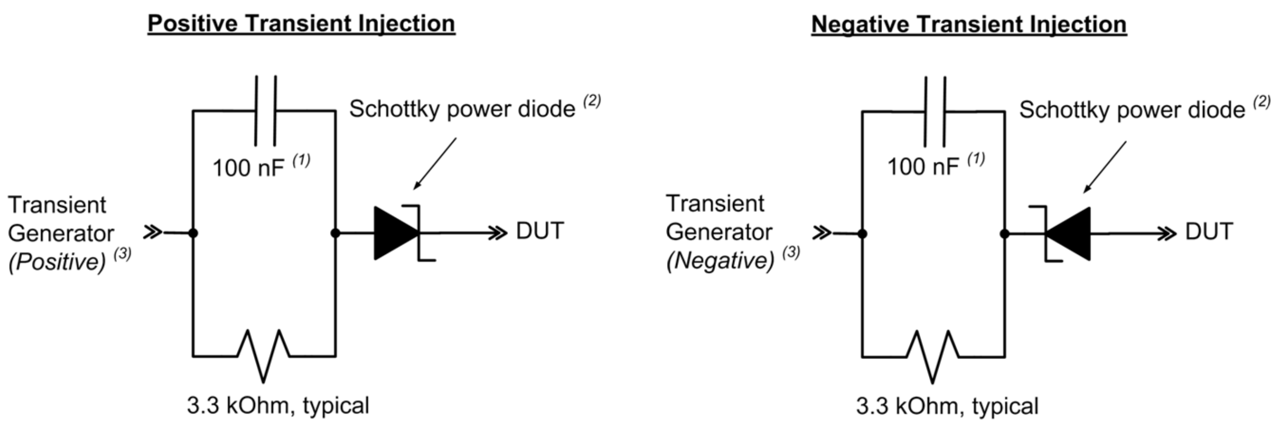
These pulses shall be applied to all inputs, outputs, and power, line by line. The test pulse voltages are set open circuit and are referenced to module ground. They are applied for approximately 9 minutes each (e.g., 500 pulses at 1 s intervals per Table 22).

3.5.4.3 Requirements. Unless otherwise specified in the Test Plan, DUT functions may only deviate beyond their acceptance criteria within a time window defined by twice (2×) the pulse duration (e.g., 100 µs for Pulse 2a). Deviations that persist beyond this 2× time interval recovery window are only permitted at a test level of higher severity than that specified in Table 22.

Table 22: Requirements of Direct Capacitor Coupling to Sensor Lines

Pulse Number	Vpeak Note 1, Note 2, Note 3	Minimum Number of Pulses	Time Between Pulses	Coupling Capacitance Note 4, Note 5
2a	-30	500 pulses	1 s	100 nF, unless otherwise specified in the test plan
	+30			

Note 1: Levels established into an open circuit.
Note 2: 2 Ω transient generator internal source impedance.
Note 3: U_A, the DC voltage for Pulse 2a, shall be set to 0 V for this test when injecting transients. However, if an RCD network is used per Note 5, U_A shall be set to +12 V when injecting negative transients.
Note 4: When performing injections for the DCC method, care must be taken to ensure that the capacitor is not damaged as a result of injection. A capacitor with typical Working Voltage DC (WVDC) of 200 V or more should be used, which provides a safety margin for the momentary transient durations and levels as shown above. Additionally, placing (2) capacitors in series (such that the resultant capacitance is 100 nF ± 10%) can increase the equivalent working voltage of the injection setup.
Note 5: Due to the potential loading/attenuation of the injected transient pulse by the DUT and its input capacitance, the GM EMC Engineer may require this value to be changed as a result of the DUT design review conducted per the GMW3103 process. Additionally, due to possible functional performance issues created by the use of this capacitor, a discharge circuit (comprised of resistor and/or diodes) may be added per approval by the GM EMC engineer (refer to Figure 9). All changes shall be specified in the test plan.



(1) Depending upon DUT I/O capacitance, this value may need to be increased by up to 10x as determined by GM EMC Engineer

(2) P/N MBR40250 or equivalent, in terms of:
- Reverse Recovery Time < 100 ns
- Min I(pk fwd, repetitive) > 42 A
- Min V(working reverse breakdown) > 200 V)

(3) For some transient generators, in order to avoid corruption of the I/O signal prior to the actual transient injected (by ensuring the diode is reverse-biased prior to testing), the DC reference supply voltage for the generator needs to be set as follows:
- select '0 volts' when injecting positive transients
- select '+12 volt' when injecting negative transients

Figure 9: Resistor-Capacitor-Diode (RCD) Injection Network

3.5.4.4 Report. The following elements shall be included in the test report:

- Performance of the functions monitored during and following application of each transient. Include actual recovery time if beyond the 2× interval window.

3.5.5 CI, 85 V Direct Capacitor Coupling. The purpose of this test is to ensure that electrical/electronic devices will not be damaged (or other devices as a result of any loss of, for instance, control signals from the DUT to some other device) as a result of excessive transients that may occur as a result of unique inductive wiring harness crosstalk.

This direct-pin transient injection test shall be required on every I/O connector pin (other than battery, ignition or accessory inputs) where the DUT does not provide for a minimum 1000 Ω series resistance between the connector pin and any active device, such as an integrated circuit, a transistor, an op-amp, an LED, etc., within the DUT.

The DUT is in a powered and fully functional mode. The specific pin(s), if applicable, will be identified during the review of the circuit schematics within the EMC process per GMW3103.

3.5.5.1 Equipment. The test equipment shall comply with ISO 7637-1 and ISO 7637-3, as well as ISO 7637-2 for the definition of Pulse 2a.

3.5.5.2 Procedure. Refer to Figure 8 for typical test setup and paragraph 3.5.4.2 for the basic procedure. Additional steps to be adhered to include:

- These pulses shall be applied to all inputs and outputs (excluding power), line by line.

  Note: Per ISO 7637-3, those paired circuits, such as the High-Speed CAN (HSCAN) communication bus, that use a twisted pair, are to be injected simultaneously.

- During the injection of the transient, the load circuit shall be momentarily disconnected (from the DUT and the injection capacitor interconnect) in order to ensure that the DUT is stressed properly and not filtered by the load circuit.

  Note: The I/O may not be able to be disconnected without powering-down the device (which is not the intent of this requirement). The specific details for such devices shall be specified in the test plan.

3.5.5.3 Requirements. Report any and all functional issues.

Unless otherwise specified in the test plan, during exposure to the pulses, deviations from DUT specified design performance is only permitted at test severity levels higher than specified in Table 23. At higher severity levels than specified in Table 23, the performance of one or more functions of the DUT may deviate from specified design performance provided following exposure to the pulses the DUT automatically recovers its full specified performance. No permanent damage to the DUT (or any of its loads that are controlled by the DUT) and loss of memory functions is permitted at the test severity level specified in Table 23.

Table 23: Requirements For I/O Transient Coupling

Pulse Number	Vpeak Note 1, Note 2, Note 3	Minimum Number of Pulses	Time Between Pulses	Coupling Capacitance Note 4, Note5	Applicable Lines
2a	-85 Vpeak	10 pulses	2 s	100 nF, unless otherwise specified in test plan	As specified in Test Plan
	+85 Vpeak				

Note 1: Levels established into an open circuit.

Note 2: 2 Ω transient generator internal source impedance.

Note 3: U_A, the DC voltage for Pulse 2a, shall be set to 0 V for this test when injecting transients. However, if an RCD network is used per Note 5, U_A shall be set to +12 V when injecting negative transients.

Note 4: When performing injections for the DCC method, care must be taken to ensure that the capacitor is not damaged as a result of injection. A capacitor with typical Working Voltage DC (WVDC) of 200 V or more should be used, which provides a safety margin for the momentary transient durations and levels as shown above. Additionally, placing (2) capacitors in series (such that the resultant capacitance is 100 nF ± 10%) can increase the equivalent working voltage of the injection setup.

Note 5: Due to the potential loading/attenuation of the injected transient pulse by the DUT and its input capacitance, the GM EMC Engineer may require this value to be changed as a result of the DUT design review. Additionally, due to possible functional performance issues created by the addition of this capacitor, a discharge circuit (comprised of resistor and/or diodes) may be added per approval by the GM EMC engineer (refer to Figure 9). All changes shall be specified in the test plan.

3.5.5.4 Report. The performance of the functions monitored during and following application of each transient.

3.5.6 CI, Alternator Direct Capacitor Coupling. This procedure and requirement is applicable to alternators only. The purpose of this test is to identify potential sensitivities to transients that may occur as a result of unique wiring harness coupling (e.g., crosstalk).

This direct-pin transient injection test shall be required on the alternator output (B+ line) and I/O lines that may be routed in the engine compartment. The DUT is in a powered and fully functional mode. The specific pin(s), if applicable, will be identified during the review of the circuit schematics within the EMC process per GMW3103.

3.5.6.1 Equipment. The test equipment shall comply with ISO 7637-1 and ISO 7637-3, as well as ISO 7637-2 for the definition of Pulse 3a/b.

3.5.6.2 Procedure. Refer to Figure 8 for typical test setup.

The transient shall be capacitively coupled from the transient generator to the applicable DUT pin by inserting a series ceramic capacitor between the generator (+) output pin and the applicable DUT pins.

The following exception to ISO 7637-3 for Direct Capacitive Coupling apply:

- The transient generator (-) shall be directly connected to the DUT ground reference for this test instead of the ground plane as defined in the ISO standard.
- The capacitor for the slow transient pulse (e.g., 100 nF) shall be used (instead of the 100 pF specified for the fast transient pulse).

The injection point shall be within 50 mm of the DUT connector, unless otherwise documented in the EMC Test Plan.

3.5.6.3 Requirements. Report any and all functional issues.

DUT functions may only deviate from the intended designed performance at a test level of higher severity than that specified in Table 24.

Table 24: Requirements of Pin Capacitive Coupling (DCC) for Alternators

Pulse Number	Vpeak Note 1, Note 2, Note 3, Note 4	Application Time	Pulse Repetition Rate	Coupling Capacitance	
				B+ output	I/O Lines
3a	-200	30 seconds	50 Hz to 350 Hz	No external capacitor	100 nF Note 5
3b	+200				

Note 1: As an exception to ISO 7637-2, the test level shall be set by connecting the generator to a 50 Ω load and the test level established across this load. The 50 Ω load shall then be disconnected before connecting the DUT to the generator.
Note 2: Pulse Burst Duration' (t_4) should be fixed at 0.1 millisecond, which produces a single pulse.
Note 3: Time Between Pulses (t_5) should cover all possible values (per the capability of the transient generator and the firmware) in the range from 2 ms to 20 ms for a transient pulse repetition frequency of 50 Hz to 350 Hz.
Note 4: The transient should be applied for 30 seconds for each "Time Between Pulses" (t_5) setting identified per Note 3.
Note 5: When performing injections for the DCC method, care must be taken to ensure that the capacitor is not damaged as a result of injection. A capacitor with typical Working Voltage DC (WVDC) of 400 V or more should be used, which provides a safety margin for the momentary transient durations and levels as shown above. Additionally, placing (2) capacitors in series (such that the resultant capacitance is 100nF ± 10%) can increase the equivalent working voltage of the injection setup.

3.5.6.4 Report. The performance of the functions monitored during and following application of each transient.

3.6 Electrostatic Discharge. The DUT I/O parametric values (e.g., resistance, capacitance, leakage current) shall be verified before the test and after completion of each ESD procedure. If, after completing the test, the parametric values have exceeded their specified limits, the DUT is non-compliant.

Note: To assess the potential for latent damage, at the discretion of the GM EMC engineer, following completion of all EMC tests at least one DUT sample may be required to undergo validation to selected durability tests defined within GMW3172. These ESD samples should be inserted into the GMW3172 validation process prior to Power Temperature Cycling (PTC). The scope of the specific tests to be performed shall be discussed and defined by the GM ENV/DUR Engineer responsible for the Component Environmental Test Plan.

3.6.1 ESD, Test During Operation of the Device (Power-On Mode).

3.6.1.1 Equipment. The ESD simulator waveform verification shall comply with ISO 10605:2001 with the following exceptions:

- The rise time requirement for ESD simulator characterization shall be:
  a. Contact discharge rise time ≤ 1 ns.
  b. Air discharge rise time ≤ 20 ns.

Note: In determining the RC time constant, calculate the RC time constant in the exponentially decaying portion of the waveform after the leading edge and/or ringing.

3.6.1.2 Procedure. Use test methods according to the relevant sections of ISO 10605:2001 with the following specifications:

- Maintain the ambient temperature at (23 ± 3) °C and the relative humidity from 20% to 40% (20 °C and 30% relative humidity preferred) during testing.
- Test each exposed surface including buttons, switches, operating shafts, etc., and all inherent seams and clearance gaps surrounding buttons, switches, displays, etc., of electrical/electronic devices normally physically accessible to an occupant inside the vehicle while seated inside the vehicle using both:
  a. Contact discharge method (contact discharge tip) and the 330 pF capacitor.
  b. Air discharge method (air discharge tip) and the 330 pF capacitor according to the test sequence in Table 25 for test numbers 1 thru 7, beginning with test sequence 1.

For test number 8, test each exposed surface including buttons, switches, operating shafts, etc., and all inherent seams and clearance gaps surrounding buttons, switches, displays, etc., of electrical/electronic devices which can be conveniently accessed when standing outside the vehicle and reaching inside without touching any other part of the vehicle (e.g., any door open, trunk open), using only the air discharge method (air discharge tip) and the 150 pF capacitor according to Table 25.

Note: The standard (1700 +300/-0) mm test harness length may be used to interconnect the DUT and simulator/load box.

Note: The monitoring instrumentation and method 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.

Note: Test number 8 is not applicable to inputs/outputs that are connected to the communication bus.

3.6.1.3 Requirements. The DUT functions shall satisfy the performance requirements of Table 25. No changes in parametric values are permitted following the ESD sequence.

Table 25: Requirements for Immunity to Electrostatic Discharge (Power-On Mode)

Discharge Note 1			Performance Requirements	Network
Sequence	Type	Level (kV)		
1	Air	± 4	No deviations allowed	For components located in the passenger compartment use: C = 330 pF R = 2 kΩ For components located in the trunk use: C = 150 pF R = 2 kΩ
2	Contact	± 4	No deviations allowed	
3	Air	± 6	No deviations allowed	
4	Contact	± 6	Momentary self-recoverable deviations allowed	
5	Air	± 8	Momentary self-recoverable deviations allowed	
6	Contact	± 8	Momentary self-recoverable deviations allowed	
7	Air	± 15	Momentary self-recoverable deviations allowed	
8	Air	± 25	Momentary self-recoverable deviations allowed	C = 150 pF R = 2 kΩ

Note 1: Three discharges are to be applied at each type, polarity, and level.

3.6.1.4 Report. The report shall contain a tabular listing showing each ESD stress level, the discharge type, and the corresponding performance exhibited by the DUT.

3.6.2 ESD, Remote Inputs/Outputs. This test method specifies a procedure for testing of components attached to all data communication buses (e.g., High-Speed Dual Wire CAN (HSCAN), Medium-Speed Dual Wire CAN (MSCAN), Low-Speed CAN (LSCAN), FlexRay, LinBus, etc., even though they may not be available at the diagnostic link connector (DLC)), or to inputs/outputs (e.g., through switches, sensors, etc.) of devices that are accessible by vehicle occupants or may be subject to ESD from an indirect charged source (e.g., wheel speed sensors, airbag control lines from mounting brackets, etc.)

3.6.2.1 Equipment. Refer to 3.6.1.1.

3.6.2.2 Procedure. The test setup shall be configured according to Figure 10.

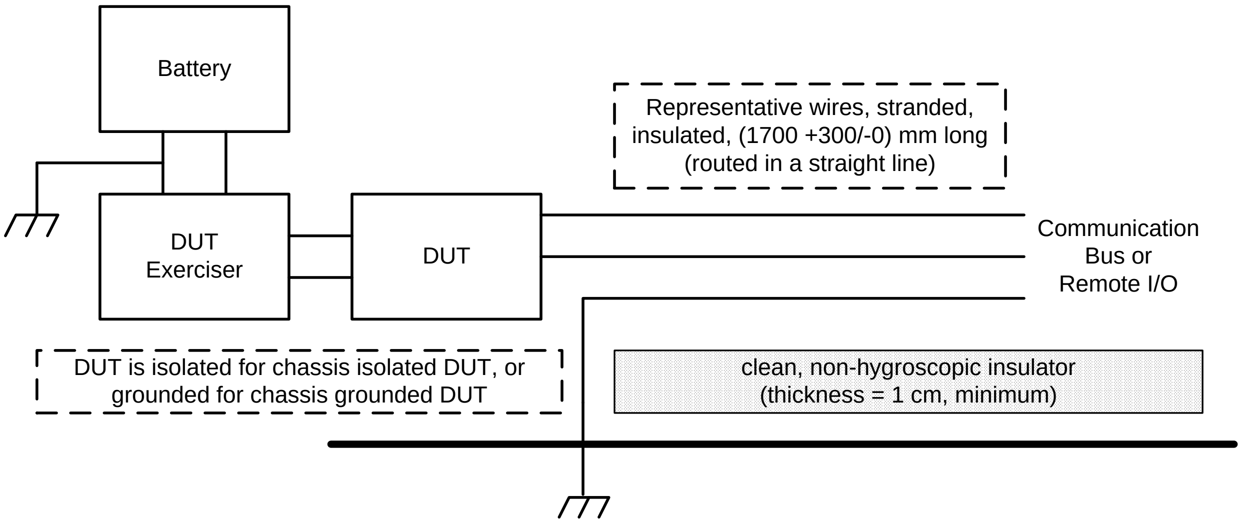


Figure 10: ESD Setup for Remote Inputs/Output

- The ambient temperature and relative humidity shall be maintained at (23 ± 3) °C and from 20% to 40%, respectively, with 20 °C and 30% relative humidity preferred, during testing.
- The DUT and the bus connector/remote I/O (e.g., switch) shall be separated by a distance of (1700 +300/-0) mm. Production representative or stranded insulated wires shall only be connected to the appropriate pins of the DUT and the test connector/remote I/O (e.g., switch). The harness shall be routed in a straight line.
- The ESD test levels, the polarity, and the order of tests shall follow Table 26. At each voltage level, test all discharge points of the test connector at both polarities.
- If the test applies to a DUT data communication bus connector, the following procedure shall be used, unless otherwise specified in the test plan:

a. The bus shall be tested in a live and maximum loaded condition. It is essential that the bus communication speed and bus load(s) is representative of the vehicle architecture. How this is accomplished shall be defined in the GMW3103 Component EMC Test Plan (Appendix B). Options can include; a 2nd DUT specially programmed for necessary “wakeup” and communication messages, or communications simulator running software to keep the DUT up and communicating, or appropriate loading in the simulator/load box and special software in the DUT to keep communication active without necessary wakeup messages.

b. The bus electrical properties (e.g., rising edge, falling edge, V[dominant], V[recessive], V[bias], etc., where applicable) shall be measured and recorded prior to any discharge.

c. The bus should be MOMENTARILY opened between the DUT and the simulator/test tool, if applicable, prior to discharge in order to protect the tool.

d. A single ESD discharge shall be applied to each active communication pin on the bus under evaluation (e.g., LSCAN (which is also referred to as SWCAN) pin, or each of HSCAN pins, etc.) at the defined voltage level in the test sequence with no external loading or clamping elements present on the bus leads at the time of discharge. Note that the intent is to discharge while the bus remains active even though the test tool may not be connected. Typical communication "bus-off" times are several seconds, so the ESD discharge should occur rapidly such that the bus remains in an active state.

e. After discharge, the bus shall be reconnected to the maximum bus loading and test tool, if applicable, to maintain operation of the device and the bus and to verify the electrical properties as noted in the second step of this process.

f. Repeat the above steps for 3 discharges at each polarity and test level, beginning with the lowest level and working through to the highest level of Table 26. Test sequence number 8 (25 kV) is not applicable to communicatio**n** busses.

- If the test applies to a non-communication I/O, such as switches, momentarily disconnect the wire (to be discharged to) from the switch and apply the ESD pulse. Reconnect the I/O after the discharge to confirm that no issues exist.

Note: Measuring instruments connected to the I/O line to be tested may influence the results of the test and/or sustain damage as a result of the test. Prior to applying discharges to an I/O line, such instruments must be disconnected from the line.

3.6.2.3 Requirements. The DUT functions shall satisfy the performance requirements of Table 26.

Table 26: Requirements for Immunity to Electrostatic Discharge of Remote Inputs/Outputs

Discharge Note 1			Performance Requirements	Network
Sequence	Type	Level (kV)		
2	Contact	± 4	No deviations allowed	C = 330 pF R = 2 kΩ
4	Contact	± 6	Momentary self-recoverable deviations allowed	
6	Contact	± 8	Momentary self-recoverable deviations allowed	
7	Air	± 15	Momentary self-recoverable deviations allowed	
8	Air	± 25	Momentary self-recoverable deviations allowed	C = 150 pF R = 2 kΩ

Note 1: Three discharges are to be applied at each type, polarity, and level.

3.6.2.4 Report. The report shall contain a tabular listing showing each ESD stress level, the discharge type, and the corresponding performance exhibited by the DUT.

3.6.3 ESD, Handling of Devices. This intent of this procedure, per ISO 10605:2001, is to assess the immunity of a device to exposure to electrostatic charging and/or discharging during packaging and handling. New with this revision of GMW3097, the scope of this procedure is modified to include the exposure of static discharging due to connecting a device to a potentially charged harness during the vehicle build process.

3.6.3.1 Equipment. Refer to 3.6.1.1.

3.6.3.2 Procedure. Prior to any testing, the parametric values of the DUT that will be used to determine compliance to the design specifications shall be recorded and presented in the test report.

- ISO 10605:2001 shall be used with the following modifications:
  a. Recessed pins of a metalized connector shall be included in this procedure (unless otherwise specified in the test plan).

b. For the ± 4 kV contact discharge to connector pins **only**:
   1. Prior to testing, all power ground terminals shall be connected to the ground plane via a grounding strap or wire with a maximum length of 20 cm. If there are multiple ground terminals which are not internally connected within the DUT (i.e., isolated from one another, such as possibly logic ground and power ground), the logic power ground shall be connected to the ground plane and the remaining ground terminals shall be subjected to ESD pulses similar to all other I/O terminal pins.
   2. 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 plane.

- Maintain the ambient temperature at (23 ± 3) °C and the relative humidity from 20% to 40% (20 °C and 30% relative humidity preferred) during testing.
- Perform an ESD discharge per Table 27 to each connector pin. After each discharge to each pin, any residual charge shall be drained by briefly connecting a 1 MΩ resistor between the pin and ground. Verify the performance requirements after completing discharge to all pins
- Remove all ground connections to the device and perform the standard packaging and handling ESD test per ISO 10605:2001 (including the 4 kV) to the case, buttons, switches, display, case screws and case openings, as well as along all air gaps that exist between buttons, faceplates, etc., that are a result of the design of the product of the DUT that are accessible during handling.
- **Note:** No additional ESD shall be applied to the connector pins for this segment of the testing.
- After each discharge to the device under test, residual charge remaining on the device under test shall be drained by briefly connecting a 1 MΩ resistor in the following sequence:
  a. Between the discharge location and ground plane;
  b. Between the ground point of the device under test and ground plane (applicable only when non testing connector pins).

Note: Charge dissipation between discharges of some modules (instrument panels, large plastic modules, etc.) may require use of an ionizer. If used, the air ionizer must be turned off and removed when each discharge is applied.

3.6.3.3 Requirements. The DUT functions shall perform according to Table 27.

Table 27: Requirements for Immunity to Electrostatic Discharge (Handling of Devices)

Discharge Note 1			Performance Requirements	Network
Sequence	**Type**	**Level (kV)**		
1	Contact	± 4	Following test, 1. All operating modes of the DUT shall comply with the intended designed performance, and 2. All DUT I/O parametric testing must show compliance with limits specified within the test plan	C = 150 pF R = 2 kΩ
2 Note 2	Contact	± 6		
3 Note 2	Air	± 8		

Note 1: Three discharges are to be applied at each type, polarity, and level.
Note 2: These levels do not apply to discharges to the pins of the device.

3.6.3.4 Report. The report shall contain a tabular listing showing each ESD stress level, the discharge type and locations, and the corresponding performance exhibited by the DUT (e.g., performance before and after in terms of operating mode compliance, parametrics, etc.)

3.7 Specific EMC Design Requirements. These requirements shall be validated by inspection and shall be documented in the Test Report.

3.7.1 Restriction of Motor Capacitance to Control Switching Transients.

Note: This requirement does not apply to BM glass wiper motors (front and rear) and HVAC blower motors (front and rear if applicable, where power is provided via a mechanical switch contact such as a relay or resistor card sliding switch). This requirement is applicable to all other mechanically-switched BM-type motors, both continuous and short-duration, as well as any AX device switching a BM-type motor (where electromechanical relays are used in the AX controller to switch the BM motor). This would exclude, for instance, solid-state PWM DC brush motor switching.

3.7.1.1 Requirements. The total capacitance added to the motor for EMC purposes shall be limited to 10 nF or less if placed directly across the motor terminals (referred to as an X-capacitor), or, using standard capacitor values, 22 nF or less if placed between either motor (+) or motor (-) and motor case (referred to as Y-capacitors). If an AX device uses on-board relays to switch power to a motor load, the total combined capacitance seen across the motor terminals (including the AX controller, any X capacitors or Y-capacitors) shall be limited to 11 nF or less. If the motor and/or device is to be integrated into an existing or in-process vehicle program (e.g., a vehicle program where some of the electrical/electronic modules where designed to the prior revisions of GMW3097), the regional EMC-responsible engineer shall be contacted for guidance on any additional/replacement EMC suppression elements which may be necessary.

Note: The rationale for this is that the other electrical/electronic devices in the vehicle were not necessarily designed for the increased levels of transient voltages permitted by this revision. Therefore, depending upon the vehicle program integration and architecture, the reduced capacitance may need to be accompanied and/or replaced by a low-capacitance transient voltage clamping device.

3.7.2 DC Brush-Commutated Motors (Limited to Glass Wiper Motor(s), HVAC Blower Motor(s), and Fuel Pump Motor) - Capacitance and Diode Transient Voltage Clamp Requirement. This requirement applies to the following DC brush-commutated motors that are supplied power via a mechanical contact such as a relay or sliding contacts (including, for instance resistance cards for HVAC blower motor control:

- All conventional BM (or AX with BM, such as a LIN-based motor design) glass wiper motor circuits (front and rear, if applicable).
- HVAC blower motor circuits (front and rear if applicable).
- Conventional BM-type fuel pumps.

Note: This requirement does not apply to a BM motor that employs Pulse Width Modulation (PWM) of its supply power for variable speed control.

3.7.2.1 Requirements. The motor design shall be able to incorporate a capacitance of up to approximately 1 microfarad (µF) across the motor terminals, with a rating (e.g., working voltage, temperature constants, etc.) consistent with the motor application. If the vehicle design requires incorporating a capacitor exceeding a nominal 10 nF (as measured directly across the motor connector terminals), transient mitigation techniques are required by the GM architecture engineer and EMC engineer.

It is recommended that a “series” RC combination circuit (e.g., comprised of a resistor of approximately 1 Ω to 10 Ω, 1/4-watt typical, in series with this large capacitor (up to 1 µF)) be installed across the motor terminals (replacing the capacitor-only solution). However, it is recognized that this may require changes to the motor to accommodate this dual-element design. As an alternative, a rectifier diode transient clamp (diode with cathode at power terminal and anode connected to the ground terminal) shall be added to the motor power circuit on the motor-side of any switching contacts (e.g., operator switch, relay contacts, etc.), either in the Bussed Electrical Center (BEC), in-harness, or possibly internal to the motor. These diodes shall be sized appropriately for their intended application (e.g., surge current, transient stall currents, thermal characteristics, etc.) Typically, these diodes are 1N5404 or equivalent, but the final determination shall be based on the specific motor requirements. The specific location of these diodes shall be determined by agreement with the GM architecture engineer and EMC engineer.

Note. The rationale for this requirement is that these motors are likely to be packaged in close proximity to the AM antenna. Therefore, to provide for acceptable AM reception in these architectures, the motors may need to incorporate a larger capacitance (e.g., greater than the 10 nF). However, these capacitors can create large capacitive discharge current transient situations when the motors are switched with mechanical switches, particularly electromechanical relays. A diode clamp significantly reduces this current pulse by clamping the capacitive charge voltage generated by the inductive load and, therefore, limiting the discharge current. The series RC circuit, if used, limits this capacitive discharge current with the addition of the 1 Ω to 10 Ω resistor, which is typically an order of magnitude larger than the inherent resistance in the circuit, which is only that of the wiring and the effective series resistance (ESR) of the capacitor.

3.7.3 Package Protection – Short-Duration Motor Inductors. This requirement is applicable to all short-duration BM-type motors (Refer to Figures 11 and 12).

3.7.3.1 Requirements. All short-duration BM motor designs shall package-protect for a series inductance (of approximately 5 microhenry (µH) in both the motor (+) and motor (-) circuits (internal to the motor). If these motors (without the inductors) are able to comply with the RE requirements contained in paragraph 3.3 of this standard, these inductors would not be populated. Vehicle performance (due to unique integration issues, such as packaging of the motor relative to the vehicle antenna system), may mandate the re-insertion of these inductors.

3.7.4 Package Protection - Short-Duration BM Motor Transient Voltage Suppression. This requirement is applicable to all short-duration BM-type motors. Refer to Figure 11 and Figure 12.

3.7.4.1 Requirements. All short-duration BM motor designs shall package-protect for a voltage clamp element (e.g., varistor, etc.) between motor (+) and motor (-) terminals.

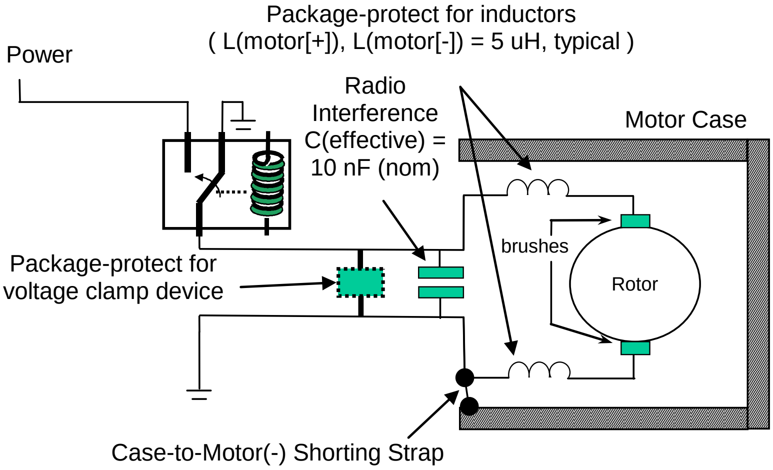


Figure 11: Short-Duration BM Motor EMC Suppression (Single-Direction and High-Side Switched)

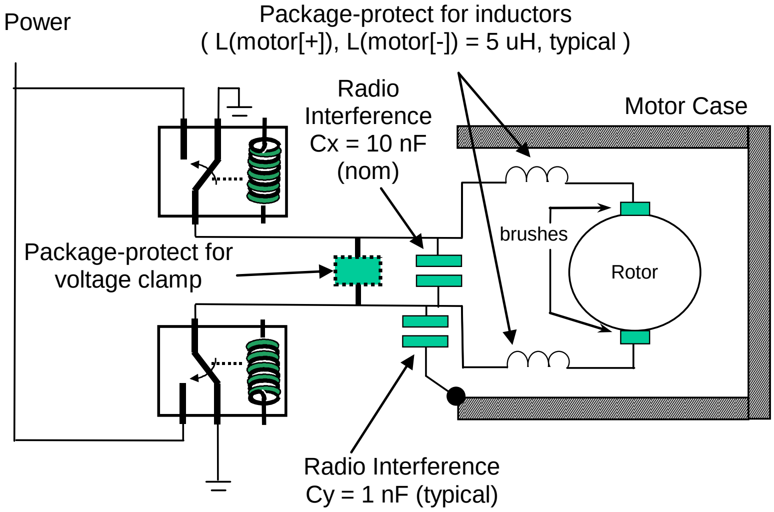


Figure 12: Short-Duration BM Motor EMC Suppression (Dual-Direction or Single-Direction and Low-Side Switched)

3.7.5 Static Charge Bleed-Off Resistor Present (DUTs with DC-Isolated Metallic Cases). This requirement is applicable to all Category A, AX, AM, or EM devices that employ a metallic enclosure which is DC-isolated from the ground pin of the device.

3.7.5.1 Requirements. All devices that employ a metallic case which is DC-isolated from vehicle/chassis ground return (e.g., the ground pin of the module) via one or more capacitor(s) shall have, as part of the circuit design, a static charge bleed-off resistor placed electrically in shunt with each of these capacitors. A typical value for the resistor is 470 kΩ to 1 MΩ. This eliminates the potential for the case to accumulate charge if packaged in the vicinity of an unintentional static charge generator, such as a rotating engine drive belt and pulley, etc.

3.7.6 Package-Protection – NTC/PTC Shunt Capacitor. This requirement is applicable to all Category D, A, AS, or AM devices that employ a Negative (or Positive) Temperature Coefficient (NTC or PTC, respectively) device as a remote temperature sensing element. If the NTC/PTC application is for temperature sensing strictly internal to a DUT (such that there is no external wire associated with the NTC/PTC circuit), this requirement does not apply.

3.7.6.1 Requirements. All devices that employ an NTC or PTC for remote temperature sensing shall package-protect for a shunt capacitor (10 nF, typical) to be placed directly across the NTC/PTC device. This eliminates the potential for RF energy-induced heating of the NTC/PTC device, resulting in potential false temperature indications.

4 Validation

4.1 General. Samples of components or material released to this specification shall be tested for conformity with the requirements of this specification and approved by the appropriate vehicle manufacturer department prior to the start of delivery of production level components or material.

Any changes to the components or material, e.g., design, function, properties, manufacturing process, and/or location of manufacture requires a new release of the product. It is the sole responsibility of the supplier to provide the customer unsolicited with documentation of any change or modification to the product/process and to apply for a new release.

If not otherwise agreed to the entire verification test shall be repeated and documented by the supplier prior to start of delivery of the modified or changed product. In some cases a shorter test can be agreed to between the appropriate vehicle manufacturer department and the supplier.

In addition, this paragraph defines the acronyms, abbreviations and special terms used in this section.

Validation Type:

- **DV** = Design Validation
- **PV** = Product Validation

The subsystem and/or component level validation must precede the initiation of vehicle validation.

4.2 Validation Cross Reference Index. Not applicable.

4.3 Supporting Paragraphs. Not applicable.

5 Provisions for Shipping

Not applicable.

6 Notes

6.1 Glossary. Not applicable.

6.2 Acronyms, Abbreviations, and Symbols.

AC	Alternating Current
ADV	Analysis Development Validation
AEMCLRP	Automotive EMC Laboratory Recognition Program
ALSE	Absorber Lined Shielded Enclosure
AM	Amplitude Modulation
AN	Artificial Network

AV	Average
B+	Battery Positive (Supply)
B-	Battery Negative (Return)
BCI	Bulk Current Injection
BEC	Bussed Electrical Center
BER	Bit Error Rate
C	Capacitance
CBCI	Common Mode BCI
CE	Conducted Emissions
CEMENT	The GM EMC and Environmental Database
CI	Conducted Immunity
CTS	Component Technical Specification
CW	Continuous Wave
DAB	Digital Audio Broadcast
DBCI	Differential Mode BCI
DC	Direct Current
DCC	Direct Pin Capacitive Coupling
DE	Designing Engineer
DLC	Diagnostic Link Connector
DoT	Department of Transportation
DRE	Design Responsible Engineer
DRG	Double Ridge Guide
DUT	Device Under Test
DV	Design Validation
EEPROM	Electronically Erasable Programmable Read-Only Memory
EMC	Electromagnetic Compatibility
ESD	Electrostatic Discharge
ESR	Effective Series Resistance
EV	Electrical Vehicle
f_0	Base Frequency
FM	Frequency Modulation
GDM	Global Document Management
GPS	Global Positioning System
HEV	Hybrid Electrical Vehicle
HSCAN	High Speed Dual Wire Controller Area Network
HVAC	Heating Ventilation Air Conditioning
ID	Identification
IF	Intermediate Frequency
IGN	Ignition
ILAC	International Laboratory Accreditation Cooperation
I/O	Input/Output
IVER	Integration Vehicle Engineering Release
k	Frequency Index Number
LED	Light Emitting Diode
LF	Low Frequency

LIN	Local Interconnect Network
LSCAN	Low Speed Controller Area Network
MRA	Mutual Recognition Arrangement
MRD	Material Required Date
MSCAN	Medium Speed Dual Wire Controller Area Network
n	Number
NTC	Negative Temperature Coefficient
OBCM	On-Board Charging Module
PCB	Printed Circuit Board
PD	Phase Duration
PEP	Peak Envelope Power
PEPS	Passive Entry Passive Start
PID	Parameter Identification
PK	Peak
PM	Phase Modulation
PRR	Pulse Repetition Rate
PTC	Positive-Temperature Coefficient
PTC	Power Temperature Cycling
PV	Product Validation
PWM	Pulse Width Modulated (or Pulse Width Modulation)
QP	Quasi-Peak
R	Resistance
RBW	Resolution Bandwidth
RC	Resistor Capacitor
RCD	Resistor Capacitor Diode
RE	Radiated Emissions
RF	Radio Frequency
RFA	Remote Frequency Actuation
RI	Radiated Immunity
RKE	Remote Keyless Entry
R-L-C	Resistor Inductor Capacitor
RMS	Root Mean Squared
RX	Receiver
SAE	SAE International, (formerly Society of Automotive Engineers)
TexDoT	Texas Department of Transportation
TPMS	Tire Pressure Monitoring System
TX	Transmitter
WVDC	Working Voltage DC

7 Additional Paragraphs

7.1 All parts or systems supplied to this standard must comply with the requirements of GMW3059, **Restricted and Reportable Substances for Parts.**

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

GMW3097

9 Release and Revisions

This standard was originated in May 1998. It was first approved by the GM Global EMC Committee in April 1999. It was first published in April 1999.

Issue	Publication Date	Description (Organization)
1	APR 1999	Initial publication.
2	FEB 2000	Editorial, was also called "revision1" (GMNA)
3	OCT 2000	Reworked, was also called "revision 2" (ITDC)
4	AUG 2001	Reworked, is also called “revision 3”. Changes against revision October 2000 (revision 2): Radiated Emissions: GPS and SDARS requirements changed, Requirements for non-spark generated noise sources added in test with artificial network. Radiated Immunity: List of Level 1 deviations changed, Reverberation Mode Tuning added, BCI requirements changed. Conducted Immunity: Pulse 2a changed, pulses 6, 7b and 8 eliminated. Electrostatic Discharge: Requirements for components located in the trunk changed, Handling requirements changed, Packaging recommendations eliminated. All paragraphs: Editorial changes and clarifications (ITDC)
5	DEC 2003	Reworked, is also called “revision 4”. Main changes against revision August 2001 (revision 3): Consolidated GMW3100 into this document, test flow chart replaced by matrix. Radiated Immunity; Level 1 & 2 functions changed, Reverb RI mode stirring expires in 2005, Frequencies adjusted, 1.5 MHz to 2 GHz only, BCI 1-10 MHz levels adjusted lower. Radiated Emissions; Reverb RE expires in 2005, Frequency range reduced and changed to individual “User Bands”, Some requirements relaxed, RF Detector changed for “Spark” category. Conducted Immunity; modified coupling clamp (3a & 3b) to include optional capacitive injection, Sensor I/O ± 30V capacitive coupled test added, optional I/O ± 85V immunity test added. ESD; Number of discharges reduced, Bus is now active and loaded during discharging. All paragraphs: Editorial changes and clarifications (GMNA and ITDC)
6	FEB 2004	Publication Feb 2004. Editorial revision, also called “revision 4”
7	JUL 2006	In response to recent vehicle issues attributable to inductive and/or capacitive crosstalk, this revision includes a new limitation on the maximum allowable capacitance for BM motors (10 nF, maximum). Associated with this change, there have been several significant modifications. First, the AM RE/CE requirements have been significantly relaxed to reflect the decreased capacitance. The conducted transient emissions have been modified to include increased levels of transient emissions (reflective of the decreased capacitance), as well as new requirements added which limit transients on the power-side of the switching relay contacts and require additional testing per ISO 7636-2, Figure 1a. Correspondingly, conducted transient immunity levels have been adjusted. This revision also incorporates an entirely new section pertaining to specific EMC design requirements for specific types of devices (paragraph 3.7). Finally, all references to Reverberation – Mode Stirring (for both RE and RI) were removed per the Revision 4 agreement of July 01, 2005, Appendix A was deleted due to publication of ISO 7637-2:2004, and minor editorial corrections were captured. This is a coordinated release with GMW3091 and GMW3103 and is also referred to as “Revision 5”.

8	APR 2012	5 Year Refresh. Changes in the standard include the following (but not limited to): General - referencing the CEMENT database and its timing milestones, adding report requirement details, and addition of a Category “AW” for wireless devices, such as key fobs; RE – added an overall 30 MHz to 1000 MHz metric analogous to regulatory references, added Tetra service protection, a new near-field magnetic field metric for 125 kHz PEPS protection, use of dual PK+AV metric for some bands, RE/CE via AN exclusion for short-duration (<1 s) motors, and standardized (1700 +300/-0) mm for CE via AN as well; RI – added I/O cycling expectations annex, require DBCI for sensors, defined calibration methods for radar pulses in new annex, increase radar pulse to 6 us for ALSE method, eliminated old mode tuning annex due to published IEC 61000-4-21 disallow use of mode-tune method for DUTs with integrated RF receivers; CE/CI – removed CE measurement for battery-side switch location, standardized CI measurement location at 50 mm for all injections (where possible), new CI unique for alternators, definition of R-C-D network for CI; ESD – eliminated 15 kV air discharge for remote I/O, ESD handling for connector pin now requires ground connection for the 4 kV test sequence; Design – allow use of standard 22 nF for Y-capacitors for motors, added note regarding use or R-C network to suppress motor transients, new static bleed-off resistor requirement for DUTs with DC-isolated metal cases, and added capacitor package protection for NTC/PTCs. (EMC/ENV GSSLT).

Appendix A - I/O Exercising

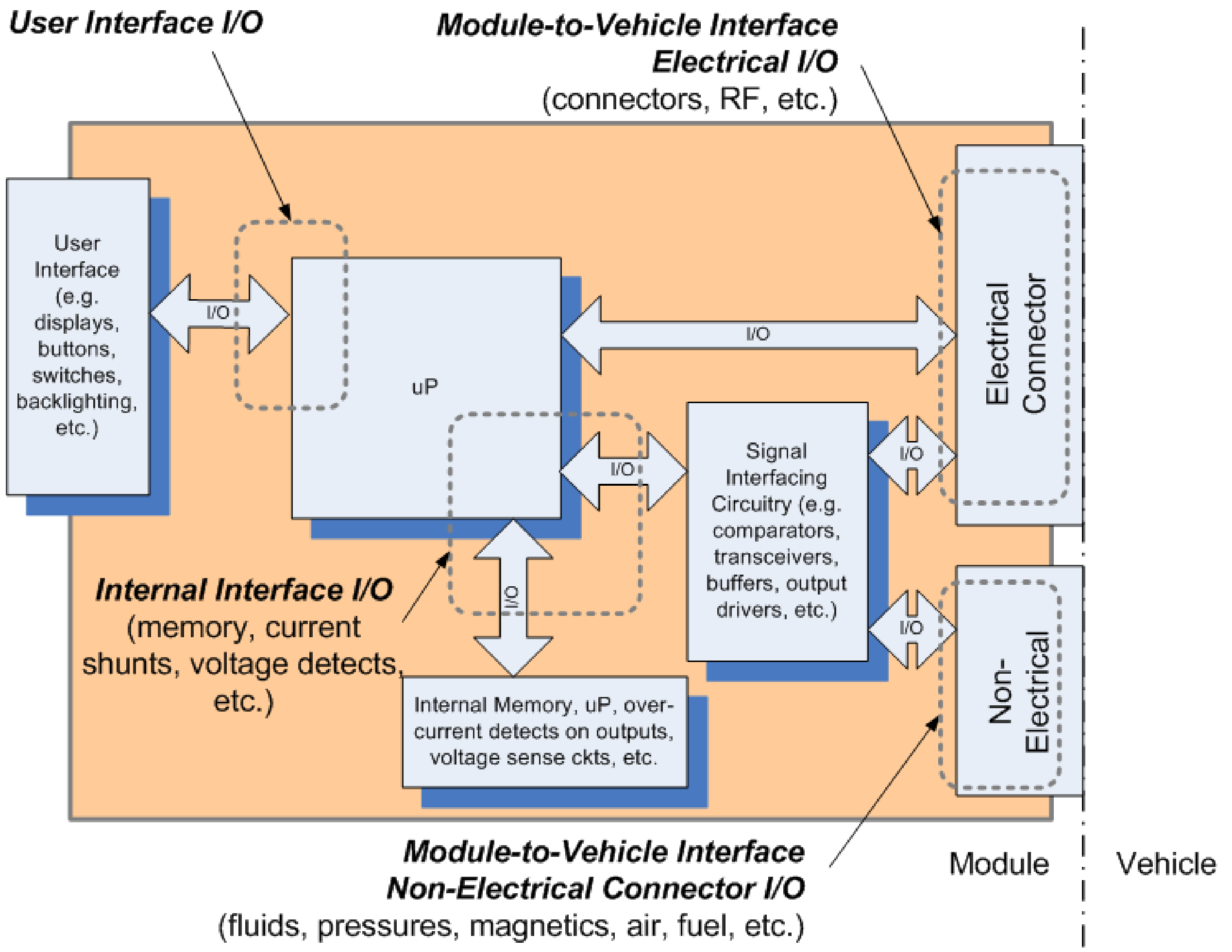


Figure A1 - Example of DUT I/O Types

Note: This appendix assumes that production software is not mandatory; the use of specialized software is acceptable.

Note: Software diagnostic timers should be reset to minimum detection values, to facilitate assertion of potential diagnostic flags during the RF exposure time (maximum 2 seconds).

Note: States/faults/issues shall be reported directly over the communication bus (i.e., Class 2, CAN, etc.) or indirectly if the communication bus is not available via the cycling of output(s) (e.g., PWM duty cycle change, telltale flash rate change, etc.)

Note: Unless otherwise specified in the EMC Test Plan, to ensure a refreshed value, all information related to data monitoring (such as analog input voltages, operating states, etc.) shall be via parameter requests (e.g., Parameter ID, or PID) and not via scheduled, or periodic, broadcast messages. This ensures bi-directional communications during immunity testing.

A1 Module to Vehicle Interface Connector and User Interface I/O

A1.1 Analog Input. Analog input shall be set nominally to the mid-range input value and value reported either directly via the DUT communications bus or, indirectly through the DUT monitoring the input and changing the state of an output in a known, pre-determined manner (e.g., change in output PWM duty cycle, illumination of LED, change in LED telltale flash rate, etc.)

A1.2 Digital (Discrete State) Input. Dynamic cycling required between asserted to non-asserted back to asserted states during radiated immunity RF **ON** exposure, report directly by communication or indirectly via output state change by detected input (e.g., PWM duty cycle change, telltale flash rate change, etc.)

A1.3 Analog Output. Expected to be set nominally to the mid range point, never at minimum or maximum value, verified using direct monitoring with fiber optic system or using "loop back" method (e.g., monitoring the simulator load using an input of the device under test).

A1.4 Digital (Discrete State) Output. Dynamic cycling required between asserted to non-asserted back to asserted states during radiated immunity RF **ON** exposure, verified using direct monitoring with fiber optic system or using "loop back" method (e.g., monitoring the simulator load using an input of the device under test).

A1.5 Communication Bus. Combination of digital and analog that requires bus messaging to a defined load. The analog properties of the bus electrical signal (e.g., v[dominant], V[recessive], etc.) shall be validated during radiated immunity testing. This may require special software to decrease the data rate to be within the bandwidth limitations of analog fiber optic transmitters.

A1.6 RF Input(s)/Output. Examples include Telematics, Global Positioning System (GPS), WiFi, Bluetooth, Remote Keyless Entry (RKE), and Tire Pressure Monitoring System (TPMS). The RF I/O is required to be exercised during EMC testing. Unless otherwise specified by the GM EMC Engineer, received signals are to be set to 3 dB above specified minimum sensitivity level. The RF level is to be established with DUT installed in test chamber. Bit Error Rate (BER) is the preferred metric with an acceptance threshold set by RF device specifications or Component Technical Specification (CTS). BER is to be monitored directly through the communication bus via parameter requests (e.g., Parameter ID, or PID) and not via scheduled, or periodic, broadcast messages. Transmitted signals are to be monitored by an appropriate RF receiver, again monitoring BER, acceptable threshold set by RF device specifications or CTS.

A2 Microprocessor Connector "Internal" I/O (I/O which does not connect to the vehicle I/O connector)

Note: For these internal I/O, monitoring shall only occur via communication bus data or via indirect methods. Direct monitoring using attachments leads to external monitoring devices shall not be included.

A2.1 Analog Input. Analog input is set to nominal operating value/condition for the specified test mode with the value reported either directly via the DUT communications bus or, indirectly through the DUT monitoring the input and changing the state of an output in a known, pre-determined manner (e.g., change in output PWM duty cycle, illumination of LED, change in LED telltale flash rate, etc.)

These functions are based on internal PCB operating conditions and are not expected to be controlled or changed during testing; it is not necessary to force a mid values for these inputs as with vehicle harness interface I/O.

A2.2 Digital (Discrete State) Input - Non-dynamic (Steady-state I/O). Examples include feedback fault indication, over/under current monitoring via discrete comparator circuit, etc.

The input is set to the nominal operating value/condition for the specified test mode with the value reported either directly via the DUT communications bus or, indirectly through the DUT monitoring the input and establishing the state of an output in a known, pre-determined manner (e.g., change in output PWM duty cycle, illumination of LED, change in LED telltale flash rate, etc.)

Not to include reset, address/data lines and communication between the microprocessor and electronically erasable programmable read-only memory (EEPROM), etc.

A2.3 Digital Discrete State Input - Dynamic Cycling I/O. Requires state change between asserted to non-asserted back to asserted states during radiated immunity RF "on" exposure, reported directly by communication or indicate indirectly via output state change by detected input (e.g., PWM duty cycle change, telltale flash rate change).

Not to include reset, address/data lines and communication between the micro and EEPROM, etc.

Note: The following microprocessor I/O do not require direct monitoring because they are indirectly monitored by the inherent operation of the device:

- Discrete outputs.
- Analog outputs.
- Internal communication bus(es).

Appendix B - Field Calibration for ALSE Procedure (RI - 1200 MHz to 1400 MHz at 600 V/m)

Due to the need for accurate generation of the high field strengths for the radar bands, field characterization shall be facilitated using the procedures outlined in this appendix. 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 (Double Ridge Guide (DRG) horn). For lower field strength testing in the 1000 MHz to 2000 MHz range, the field characterization delineated in ISO 11452-2 shall be used.

B1 CW E-Field Probe Method

B1.1 When using this method, the orientation of the CW E-field probe axes with respect to the surface of the dielectric support and the transmit antenna are specifically defined. Figure B1 and Figure B2 illustrate positioning for two common probe styles. Note that for some probes, special consideration must be given to assure they are oriented correctly. In Figure B2, 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. Note that for either probe, its phase center (probe axis origin) is 150 mm above the surface of the ground plane used during actual testing.

B1.2 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 that the field probe **facilitate separate field axis readings**. Field probes that produce only a vector summation of the measured field shall not be used.

B1.3 Additional requirements include:

- The phase center of the field probe is positioned 150 mm above the surface of the ground plane used during actual testing.
- Peak RMS Forward Power shall be the reference parameter for characterization of the field. This requires the use of a power meter equipped with Peak Envelope Power (PEP) sensors. Although not recommended, a spectrum analyzer may be used (instead of PEP sensors) for measurement of the peak RMS forward power. If the spectrum analyzer is used, it shall be tuned to each individual frequency using zero span setting with a minimum measurement bandwidth of 3 MHz (for both the resolution or intermediate frequency (IF) bandwidth and the video bandwidth, if applicable).
- Pulse modulation characteristics shall conform to that illustrated in Figure B3. The peak RMS forward power (P_{PULSE}) used for pulsed modulation testing shall be the same as the CW calibration power (P_{CW_CAL}) (i.e., $P_{PULSE} = P_{CW\_CAL}$).
- Characterization shall be performed using CW at the required field strengths in Table 11, thus requiring a CW E-field probe which is capable of measuring to these fields listed in Table 11 (e.g., 600 V/m).
- **Note:** If the CW E-field probe is not capable of measuring the fields required, or if a Pulsed-Only amplifier is required in order to achieve the target field strengths, then it is acceptable to calibrate the chamber at a lower CW level using a CW power meter and CW amplifier (in order to derive the relationship between forward power and field strength). It is then acceptable to scale the forward power levels (as measured with a Peak Envelope Power (PEP) sensor for the power meter) accordingly to the corresponding target E-Field during actual testing. This requires that the setup, such as geometry, cabling, and transmit antenna, remains constant (excluding CW versus PEP sensors and possibly CW versus Pulsed-Only amplifiers).

B1.4 The E-field probe shall be specifically calibrated at 1.3 GHz, as a minimum.

B2 Pulsed E-Field Probe Method

B2.1 Use of E-field probes capable of direct measurement of a pulsed field is under consideration only and shall not be used as a means of field calibration at this time.

B3 Antenna Method

B3.1 Figure B4 illustrates the setup when using a receiving antenna for field characterization. This method may be used when using either CW or pulsed amplifiers. Typical receive antennas include, but are not limited to:

- ETS Lindgren: DRG 3115.
- Antenna Research: DRG118/A.
- Rohde & Schwarz: HF906.

B3.2 Additional requirements include:

- The phase center of the antenna is positioned 150 mm above the surface of the ground plane used during actual testing.
- Peak Forward Power shall be the reference parameter for characterization of the field. This requires the use of a power meter equipped with Peak Envelope Power (PEP) sensors. Although not recommended, a spectrum analyzer may be used in (instead of PEP sensors) for measurement of the peak RMS forward power. If the spectrum analyzer is used, it shall be tuned to each individual frequency using zero span setting with a minimum measurement bandwidth of 3 MHz (for both the resolution or IF bandwidth and the video bandwidth, if applicable).
- Pulse modulation characteristics shall conform to that illustrated in Figure B3. The maximum RMS forward power (P_{PULSE}) used for pulsed modulation testing shall be the same as the CW calibration power (P_{CW_CAL}) (i.e. $P_{PULSE} = P_{CW\_CAL}$).

Characterization shall be performed using the required field strengths in Table 11 (e.g., 600 V/m).

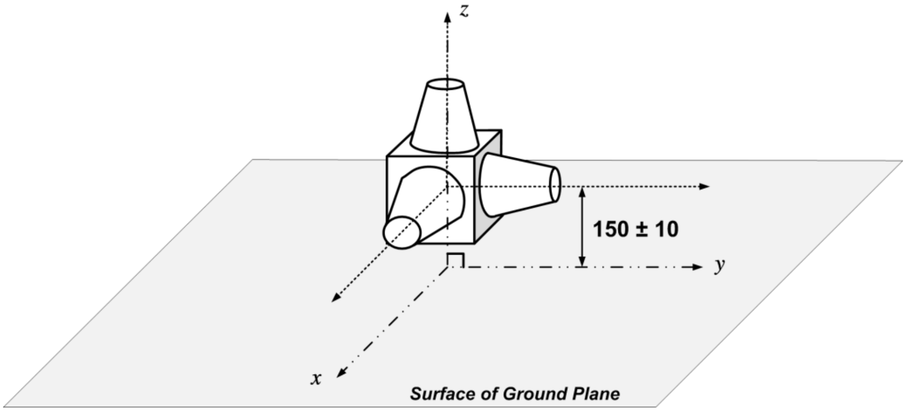
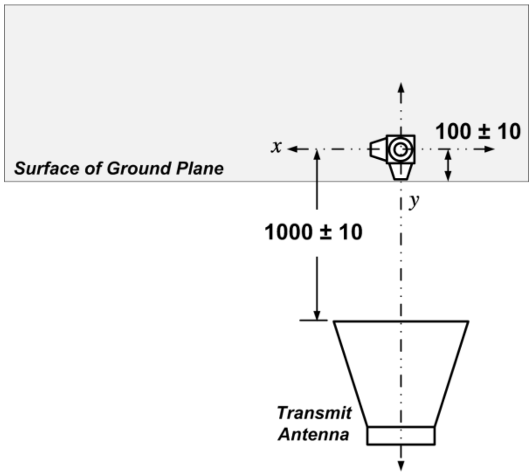
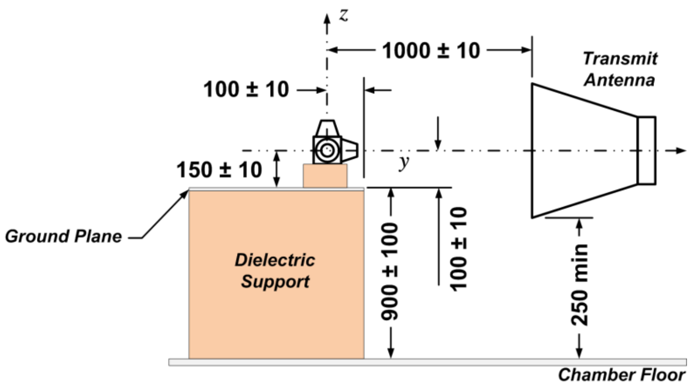
Isometric View (Dimensions in millimeters)	
Top View (Dimensions in millimeters)	
Side View (Dimensions in millimeters)	

Figure B1 - Field Probe (Type A) Positioning Requirements

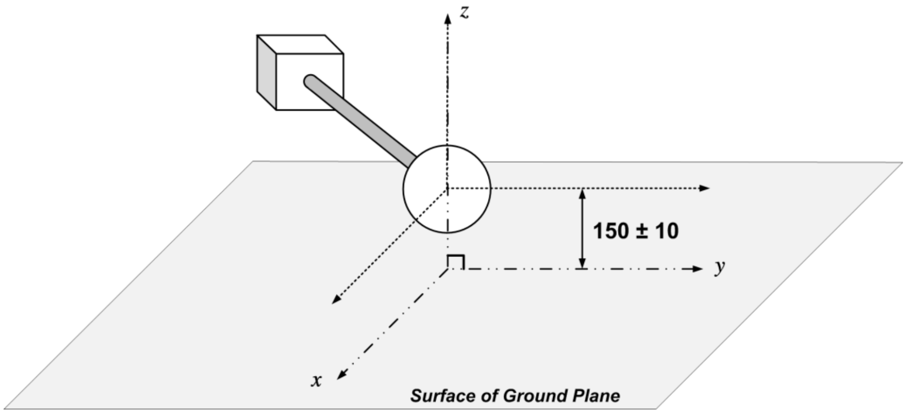
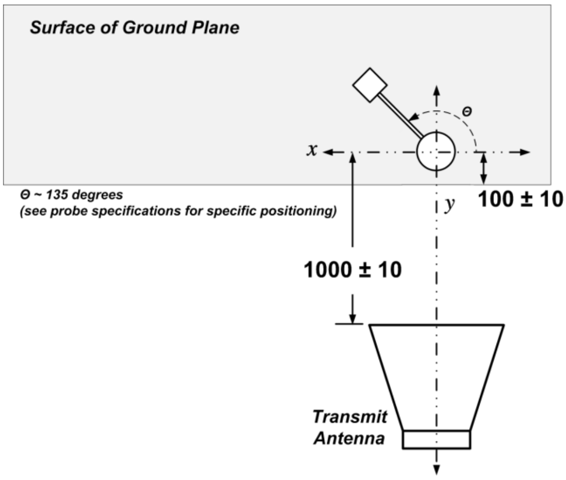
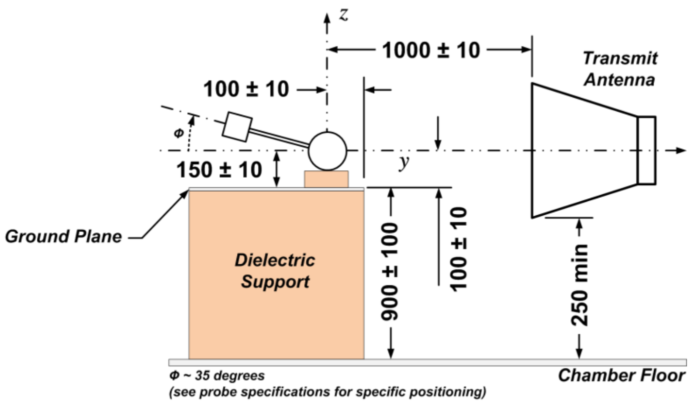
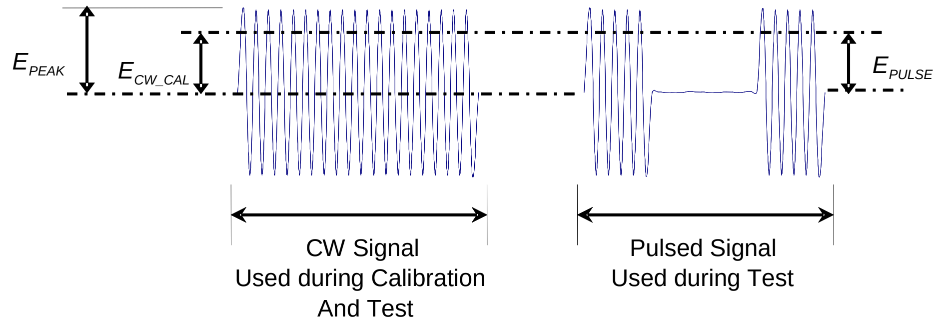
<table>
<tr><td>Isometric View
(Dimensions in millimeters)</td><td>
</td></tr>
<tr><td>Top View
(Dimensions in millimeters)</td><td>
</td></tr>
<tr><td>Side View
(Dimensions in millimeters)</td><td>
</td></tr>
</table>

Figure B2 - Field Probe (Type B) Positioning Requirements



E_{CW_CAL} = Field Strength (RMS) at levels listed in Table 11

Figure B3 - Peak Level Conservation Requirement for Pulse Modulation

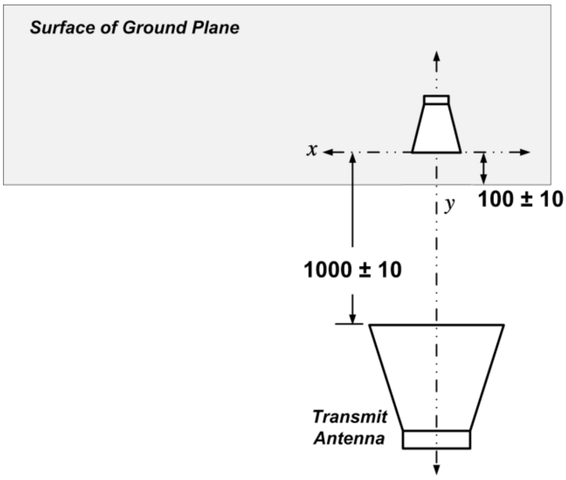
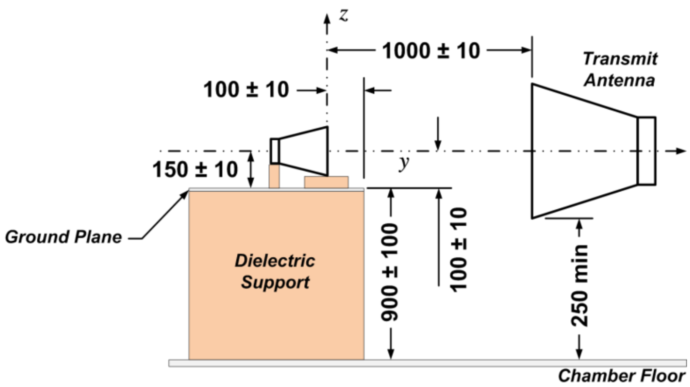
Top View (Dimensions in millimeters)	
Side View (Dimensions in millimeters)	

Figure B4 - Receive Antenna Positioning Requirements