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

Requirements and Verification

1 Introduction

In the event of a conflict between the text of this specification and the documents cited herein, the text of this specification takes precedence.

Nothing in the specification, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

1.1 Scope

This document applies to the Electromagnetic Compatibility (EMC) of electrical/electronic components and subsystems for passenger vehicles, light duty trucks and medium 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 (All three documents of equal revision carry the same release date).

Note: Earlier versions of GMW12559, GMW12002V, GMW12002R, and GMW3100, have been integrated into GMW3097 for ease of use.

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.

2 References

Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ISO 7637-1, ISO 7637-3, ISO 11452-1, ISO 11452-2, ISO 11452-4, ISO 10605, IEC CISPR 25, IEC 61000-4-21, SAE J1113-22, SAE J1113-27

2.2 GM Standards/Specifications.

GMW3091, GMW3103, GM9114P

3 Requirements

Validation testing after 01 July 2005 must be performed at a laboratory that has received recognition through the Automotive EMC Laboratory Recognition Program (AEMCLRP).

To obtain recognition, a laboratory must provide evidence of:

a) ISO17025 certification to at least the base specifications that apply to GMW EMC test procedures. The base specifications are listed in Table 1

Table 1: AEMCLRP List of Base Specifications

Procedure Name	Base Specification
Radiated Emissions Anechoic	IEC CISPR 25
Radiated Emissions Reverb	GM9114P
Bulk Current Injection	ISO11452-4
Radiated Immunity Anechoic	ISO11452-2
Radiated Immunity Reverb	IEC 61000-4-21
Transient Immunity	ISO7637-2.3 (See Annex A) and ISO7637-3
Electrostatic Discharge	ISO10605

b) Demonstrate meeting proficiency test requirements where applicable. This requires testing a defined artifact and comparing results against results obtained at reference laboratory(ies). Comparisons must meet the metrics detailed in the AEMCLRP.

3.1 Product Characteristics.

3.1.1 Sample Size

Minimum of two (2) samples shall be tested.

3.1.2 Power Supply

The supply voltage shall be 13.5 (+0.5/-1) V, unless otherwise stated in the test plan.

3.2 Performance Requirements.

The DUT (Device Under Test) 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.

Deviations from the requirements and/or test procedures shall have been agreed upon prior to testing. Such deviating requirements shall be specified in the 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 2 may not be all inclusive. The final list of required tests is to be determined by the EMC Engineer during the GMW3103 process.

In this document, electronic modules, electric motors and inductive devices are classified into categories that determine the appropriate test requirements.

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

Table 2: EMC Test Selection Matrix

Test		Paragraph Numbers	Others		Electronic Components				Motors	
			D	R	A	AS	AM	AX	BM	EM
Emissions 3.3	ALSE CE, Artificial Network Reverberation Mode Stirring	3.3.1 3.3.2 3.3.3			X	X	X	X	X	X
Immunity 3.4	Bulk Current Injection Anechoic Chamber Reverb, Mode Tuning Reverb, Mode Stirring	3.4.1 3.4.2 3.4.3 3.4.4			X	X	X	X		X
	Magnetic Field	3.4.5					X			X (Note)
Transients 3.5	Conducted Emissions	3.5.1		X				X	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				
	(Optional) CI, 85V Direct Capacitor Coupling	3.5.5			X		X	X		
ESD 3.6	Powered-On Mode	3.6.1			X		X	X		
	Remote I/O	3.6.2			X		X	X		
	Handling of Devices	3.6.3	X		X	X	X	X		X

Note: Applies only to motors with integral hall effect sensors

Electronic module categories:

D:	Module containing only diodes and mechanically switched to battery (e.g. LED Center High Mounted Stop Lamp display, Inflator Shut Off Switch)
A:	A component or module that contains active electronic devices. Examples: analog op amp circuits, switching power supplies, microprocessor controllers and displays.
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.
AM:	An electronic component or module that contains magnetically sensitive elements.
AX:	An electronic module that controls an inductive device (e.g. electric or electronically controlled motor(s), solenoids, etc.) internal or external to its package.

Electric motors:

BM:	A brush commutated electric motor.
EM:	An electronically controlled or commutated electric motor.

Inductive devices:

R:	Relays and solenoids and horns

3.2.1 Report

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

- Internal unique test report number.
- Part number and description of the DUT, Hardware and Software Version.
- Date of test.
- Facility name.
- Requesting engineer.
- Requesting division/company.
- Type of test (Design Validation or Product Validation).
- Test Equipment Software Revision (if test equipment is software controlled).
- Copy of the original test plan.
- Any deletion from or addition to the test procedure.
- Description of the test set-up and equipment used.
- Photograph of the test set-up.
- Part number and description of the harness.
- Equipment calibration data, if required by the test plan, unless available in the facility records.

3.3 Radiated Emissions (RE) and Conducted Emissions (CE)

Prior to measurement of the DUT emissions, test setup ambient levels (i.e. load/box, simulator energized without DUT), the ambient levels shall not be above the limit and should be 6 dB below the limit. This data shall be supplied within the test report.

Noise is divided into two different types:

- Non-spark generated noise: Noise generated by electronic sources, such as microprocessors, clocks, PWM etc.
- Spark generated noise: Noise generated by sparks, such as ignition systems, short and long duration brush type motors etc.

Short duration motors (e.g. seat, lumbar, door lock motors, etc.) shall be designed with a FULL SUPPRESSION version and shall comply with the complete set of radiated emissions requirements as detailed in radiated emissions Table 5 (ALSE) or Table 10 (Reverberation)

For GM North America platforms only, a REDUCED SUPPRESSION (parts delete) version of the same motor shall be made available, that shall comply with *only* the G1 (AM) band in Table 5 (ALSE) or Table 10 (Reverberation). The decision to utilize these reduced suppression short duration motors shall be made on a platform-by-platform basis.

Note: All motors are expected to meet both the requirements of Table 7 (Artificial Network) and Table 19 (Conducted Transient Emissions).

The RF spectrum reporting has been divided into individual 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 onboard receiver bands or from 150 kHz to 1583 MHz, or in any other appropriate number of sub bands. The test results should be reported as shown in Annex D.

The requirements are applicable to the following:

- Categories A, AS, AM - These devices shall meet the "Non-Spark" limits
- Categories AX, EM - These devices shall meet both "Non-spark" and "Spark" limits, the controller and actual inductive load shall be tested as a system
- Category BM - These devices shall meet the "Spark" limits

Categories "AX" and "EM" shall be combined for testing. If the combined emissions exceed the "Non-Spark" limit, the average detector (AV) may be used in place of the peak (PK) detector for those bands where the "Non-Spark" limit was exceeded. If the AV detector is used, the requirement is more restrictive than the PK requirement by 6 dB (PK requirement – 6 dB = AV requirement). This is based on the inability to detect the module noise over the arcing noise of a motor when using the PK detector.

The use of a PK detector at greater 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 resweep 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)

RE, Reverberation, Mode Stirring section 3.3.3 is an alternative to this test method but can only be used until 01 July 2005.

Equipment

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

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.

Procedure

Below 30 MHz one DUT orientation (as in the vehicle if known) is required, above 30 MHz three orthogonal DUT orientations are required. The maximum level at each frequency shall be reported.

For the frequency range (1...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.

Requirements

The field strength level of the radiated emissions shall not exceed the levels of Table 3,

Table 4 and Table 5.

Table 3: Radiated Emissions Absorber Lined Chamber (ALSE) Non-Spark Requirements

ID #	Region	RF Service *(User Band)* (MHz)	Frequency Range (MHz)	Conditions	Non-Spark Limit (dBμV/m)	Note
EU1	Europe	Long Wave	0.15 - 0.28	RBW 9/10 kHz, Step Size ≤ 5 kHz, Time/Step > 5ms	41 PK	1
G1	Global	Medium Wave / AM	0.53 - 1.71		30 PK	
NA1	America	DoT I *(45.68 - 47.34)*	45.2 - 47.8		12 PK	2
G2	Global	4 Meter *(66 - 87.2)*	65.2 - 88.1		12 PK	2
JA1	Japan	FM I *(76 – 90)*	75.2 - 90.9		12 PK	2
G3	Global	FM II *(87.5 – 108)*	86.6 - 109.1		12 PK	2
G4	Global	2 Meter *(142 – 175)*	140.6 - 176.3		12 PK	2
EU2	Europe	DAB *(174.1 – 240)*	172.4 - 242.4		12 PK	2
G5	Global	RFA/TPMS I	310 - 320		20 PK	
G6	Global	RFA/TPMS II	429 - 439		25 PK	
G8	Global	GPS	1567 -1574 - 1576 - 1583		50-10-10-50 AV	3, 4

Note 1: Optional, applies to products intended for Fiat vehicles

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

Note 3: Bandwidth reduction or a high gain low noise amplifier should be used in order to accurately measure these low signal levels

Note 4: Requirement is 50 dBμV/m at 1567 MHz, decreasing linearly in frequency to 10 dBμV/m at 1574 MHz, 10 dBμV/m between 1574 and 1576 MHz, 10 dBμV/m at 1576 MHz increasing linearly in frequency to 50 dBμV/m at 1583 MHz

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

ID #	Region	RF Service *(User Bands)* (MHz)	Frequency Range (MHz)	Conditions	Spark Limit (dBμV/m)	Note
EU1	Europe	Long Wave	0.15 - 0.28	RBW 9 kHz, Step Size ≤ 50 kHz, Time/Step = 1 sec	63 QP	1
G1	Global	Medium Wave / AM	0.53 - 1.71		24 QP	
NA1	America	DoT I *(45.68 - 47.34)*	45.2 - 47.8	RBW 120 kHz, Step Size ≤ 1 MHz, Time/Step = 1 sec	24 QP	2
G2	Global	4 Meter *(66 - 87.2)*	65.2 - 88.1		24 QP	2
JA1	Japan	FM I *(76 – 90)*	75.2 - 90.9		24 QP	2
G3	Global	FM II *(87.5 – 108)*	86.6 - 109.1		24 QP	2
G4	Global	2 Meter *(142 – 175)*	140.6 – 176.3		24 QP	2
EU2	Europe	DAB *(174.1 – 240)*	172.4 - 242.4		24 QP	
G5	Global	RFA/TPMS I	310 - 320		30 QP	
G6	Global	RFA/TPMS II	429 - 439		30 QP	

Note 1: Optional, applies to products intended for Fiat vehicles
Note 2: Frequency Range includes a 1% guard band surrounding the User Bands between 30 MHz and 240 MHz

Table 5: Radiated Emissions Absorber Lined Chamber (ALSE) Spark Requirements – Short Duration Motors

ID #	Region	RF Service *(User Band)* (MHz)	Frequency Range (MHz)	Conditions	Spark Limit (dBμV/m)	Note
EU1	Europe	Long Wave	0.15 - 0.28	RBW 9 kHz, Step Size ≤ 50 kHz, Time/Step = 1 sec	63 QP	1
G1	Global	Medium Wave / AM	0.53 - 1.71		24 QP	
JA1	Japan	FM I *(76 – 90)*	75.2 - 90.9	RBW 120 kHz, Step Size ≤ 1 MHz, Time/Step = 1 sec	24 QP	2, 3
G3	Global	FM II *(87.5 – 108)*	86.6 - 109.1		24 QP	2, 3
EU2	Europe	DAB *(174.1 – 240)*	172.4 - 242.4		24 QP	2, 3

Note 1: Optional, applies to products intended for Fiat vehicles
Note 2: Frequency Range includes a 1% guard band surrounding the User Bands between 30 MHz and 240 MHz
Note 3: Does not apply to specific ”reduced suppression” (parts delete) motors for GMNA platforms

Report

The test report data summary shall be formatted as shown in Annex D, a single page including tabularized data, requirements, band ID, region, RF service name, frequency range, and maximum level (dBμV/m).

End of section 3.3.1 Radiated Emissions (ALSE)

3.3.2 CE, Artificial Network (AN)

All DUT B+ and switched B+ shall be commonly connected to the output of the artificial network.

Equipment

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

Procedure

Use test method IEC CISPR 25 with the following exception:

For the length of the power lines within the wiring harness the requirements of IEC CISPR 25 apply. For other wires within the wiring harness alternatively a length of (1700 +300/-0) mm can be chosen.

Requirements

The voltage level of the conducted emissions shall not exceed the levels of Table 6 and Table 7. The limits apply for artificial networks without correction factors applied.

Table 6: Conducted Emissions Artificial Network (AN) Non-Spark Requirements

ID #	Region	RF Service	Frequency Range (MHz)	Conditions	Non-Spark Limit (dBµV)	Note
EU1	Europe	Long Wave	0.15 - 0.28	RBW 9/10 kHz, Step Size ≤ 5 kHz, Time/Step > 5ms	73 PK	1
G1	Global	Medium Wave / AM	0.53 - 1.71		42 PK	

Note 1: Optional, applies to products intended for Fiat vehicles

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

ID #	Region	RF Service	Frequency Range (MHz)	Conditions	Spark Limit Limit (dBµV)	Note
EU1	Europe	Long Wave	0.15 - 0.28	RBW 9 kHz, Step Size ≤ 50 kHz, Time/Step = 1 sec	80 QP	1, 2
G1	Global	Medium Wave / AM	0.53 - 1.71		50 QP	2

Note 1: Optional, applies to products intended for Fiat vehicles
Note 2: If using PK detector if QP is not available, add 13 dB to QP limit (valid until 01 July, 2005)

Report

The test report data summary shall be formatted as shown in Annex D, a single page including tabularized data, requirements, band ID, region, RF service name, frequency range, and maximum level (dBµV/m).

End of section 3.3.2 Conducted Emissions with AN

3.3.3 RE, Reverberation, Mode Stirring

This alternate test method can only be used until 01 July 2005.

If this alternate test method is used correlation must be established with GMNA Milford Proving Ground facility.

Requirements

The field strength of the spark generated and non-spark generated radiated emissions measured with PK detector shall not exceed the levels of Table 8, Table 9 and Table 10.

Table 8: Radiated Emissions Reverberation Chamber (Mode Stirring) Non-Spark Requirements

ID #	Region	RF Service *(User Bands)* (MHz)	Frequency Range (MHz)	Conditions	Non-Spark Limit (dBµV/m)	Note
EU1	Europe	Long Wave	0.15 - 0.28	RBW 9/10 kHz, Step Size ≤ 5 kHz, Time/Step > 5ms	38 PK	1
G1	Global	Medium Wave / AM	0.53 - 1.71		38 PK	
NA1	America	DoT I *(45.68 - 47.34)*	45.2 - 47.8		20 PK	2
G2	Global	4 Meter *(66 - 87.2)*	65.2 - 88.1		20 PK	2
JA1	Japan	FM I *(76 – 90)*	75.2 - 90.9		20 PK	2
G3	Global	FM II *(87.5 – 108)*	86.6 - 109.1		20 PK	2
G4	Global	2 Meter *(142 – 175)*	140.6 - 176.3		20 PK	2
EU2	Europe	DAB *(174.1 – 240)*	172.4 - 242.4		20 PK	2
G5	Global	RFA/TPMS I	310 - 320		20 PK	
G6	Global	RFA/TPMS II	429 - 439		30 PK	
G8	Global	GPS	1567 -1574 - 1576 - 1583		64-24- 24-64 PK	3, 4

Note 1 Optional, applies to products intended for Fiat vehicles

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

Note 3 Bandwidth reduction or a high gain low noise amplifier should be used in order to accurately measure these low signal levels

Note 4 Requirement is 64 dBµV/m at 1567 MHz, decreasing linearly in frequency to 24 dBµV/m at 1574 MHz, 24 dBµV/m between 1574 and 1576 MHz,24 dBµV/m at 1576 MHz increasing linearly in frequency to 64 dBµV/m at 1583 MHz

Note: Requirements > 1 GHz assume 0 dBi gain for the antenna, therefore the antenna manufacturer‘s antenna factor figures need to be corrected.

AF(dB) = 20 log(F) - 10 log(G) - 29.78

Where:

AF = Antenna Factor

F = Frequency in MHz

10 log(G) = Gain in dBi

Table 9: Radiated Emissions Reverberation Chamber (Mode Stirring) Spark Requirements

ID #	Region	RF Service *(User Bands)* (MHz)	Frequency Range (MHz)	Conditions	Spark Limit (dBμV/m)	Note
EU1	Europe	Long Wave	0.15 - 0.28	RBW 9/10 kHz, Step Size ≤ 5 kHz, Time/Step > 5ms	83 PK	1
G1	Global	Medium Wave / AM	0.53 - 1.71		44 PK	
NA1	America	DoT I *(45.68 - 47.34)*	45.2 - 47.8	RBW 100/120 kHz, Step Size ≤ 50 kHz, Time/Step > 20 ms	63 PK	2
G2	Global	4 Meter *(66 - 87.2)*	65.2 - 88.1		63 PK	2
JA1	Japan	FM I *(76 – 90)*	75.2 - 90.9		63 PK	2
G3	Global	FM II *(87.5 – 108)*	86.6 - 109.1		63 PK	2
G4	Global	2 Meter *(142 – 175)*	140.6 - 176.3		63 PK	2
EU2	Europe	DAB *(174.1 – 240)*	172.4 - 242.4		63 PK	2
G5	Global	RFA/TPMS I	310 - 320		63 PK	
G6	Global	RFA/TPMS II	429 - 439		73 PK	

Note 1: Optional, applies to products intended for Fiat vehicles
Note 2: Frequency Range includes a 1% guard band surrounding the User Bands between 30 MHz and 240 MHz

Table 10: Radiated Emissions Reverberation Chamber (Mode Stirring) Spark Requirements – Short Duration Motors

ID #	Region	RF Service *(User Bands)* (MHz)	Frequency Range (MHz)	Conditions	Spark Limit (dBμV/m)	Note
EU1	Europe	Long Wave	0.15 - 0.28	RBW 9/10 kHz, Step Size ≤ 5 kHz, Time/Step > 5ms	83 PK	1
G1	Global	Medium Wave / AM	0.53 - 1.71		44 PK	
JA1	Japan	FM I *(76 – 90)*	75.2 - 90.9	RBW 100/120 kHz, Step Size ≤ 50 kHz, Time/Step > 20 ms	63 PK	2, 3
G3	Global	FM II *(87.5 – 108)*	86.6 - 109.1		63 PK	2, 3
EU2	Europe	DAB *(174.1 – 240)*	172.4 - 242.4		63 PK	2, 3

Note 1: Optional, applies to products intended for Fiat vehicles
Note 2: Frequency Range includes a 1% guard band surrounding the User Bands between 30 MHz and 240 MHz
Note 3: Does not apply to specific “reduced suppression” (parts delete) motors for GMNA platforms

Equipment

Receiver: This test method was developed using a spectrum analyzer. Other receivers may also be used if correlation with the spectrum analyzer has been established.

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.

Antennas: The antennas listed in Table 11 should be used. This is not an inclusive list, other linearly polarized antennas may be substituted:

Table 11: RE Reverberation Chamber Test Antennas

Antenna	Frequencies Covered (MHz)	Reference Point
Active Monopole (EMCO 3301B or equivalent)	0.150 - 30	Intersection of rod and ground plane
Biconical	30 - 200	Midpoint of elements
Log-Periodic	200 - 1000	Front boom tip
Horn	1000 -1583	Front aperture

Simulator: A simulator with a 3-meter harness containing all power/signal leads and loads necessary to operate the DUT shall be supplied. Shielded or twisted leads should be present only if designed into the actual production system.

Test Chamber: Shielded enclosure. In order to correlate with GM's test facility at Milford Proving Ground, it is recommended that the test be performed in a shielded enclosure with the following nominal inside dimensions: 3.61 m (length) by 4.83 m (width) by 3.05 m (height)

Tuner or Stirrer: Refer to SAE J1113/27 for mode stirrer specifications. Other stirrer designs may be used if correlation is established.

Procedure

Use the test setup according to Figure 1.

The applicable frequency range is divided into bands as shown in Table 8 (Non-Spark) and Table 9 (Spark). A complete dataset of field strength vs. frequency shall be reported for each band.

Detector: Use maximum positive peak and hold detector (MAX HOLD, PK).

Sweep Time: The minimum calibrated sweep time shall be used, typically in the range of (20...500) ms for a single sweep of the analyzer (receiver).

Scan Time: The minimum time interval for a given frequency band in which the analyzer (receiver) is collecting multiple sweep datasets (in a MAX HOLD, PK mode). For this reverberation technique, this scan time shall be 60 s for each band.

Polarization: Only vertical polarization shall be used.

Mode stirring: Above 30 MHz mode stirring shall be used. Mode stirring is a reverberation technique that uses a continuously rotating stirrer during testing. Below 30 MHz mode stirring is not allowed. The stirrer shall be in its home position. The home position is defined as: Mode stirrer is parallel to the DUT harness. The stirrer revolution rate is nominally 5 seconds per revolution.

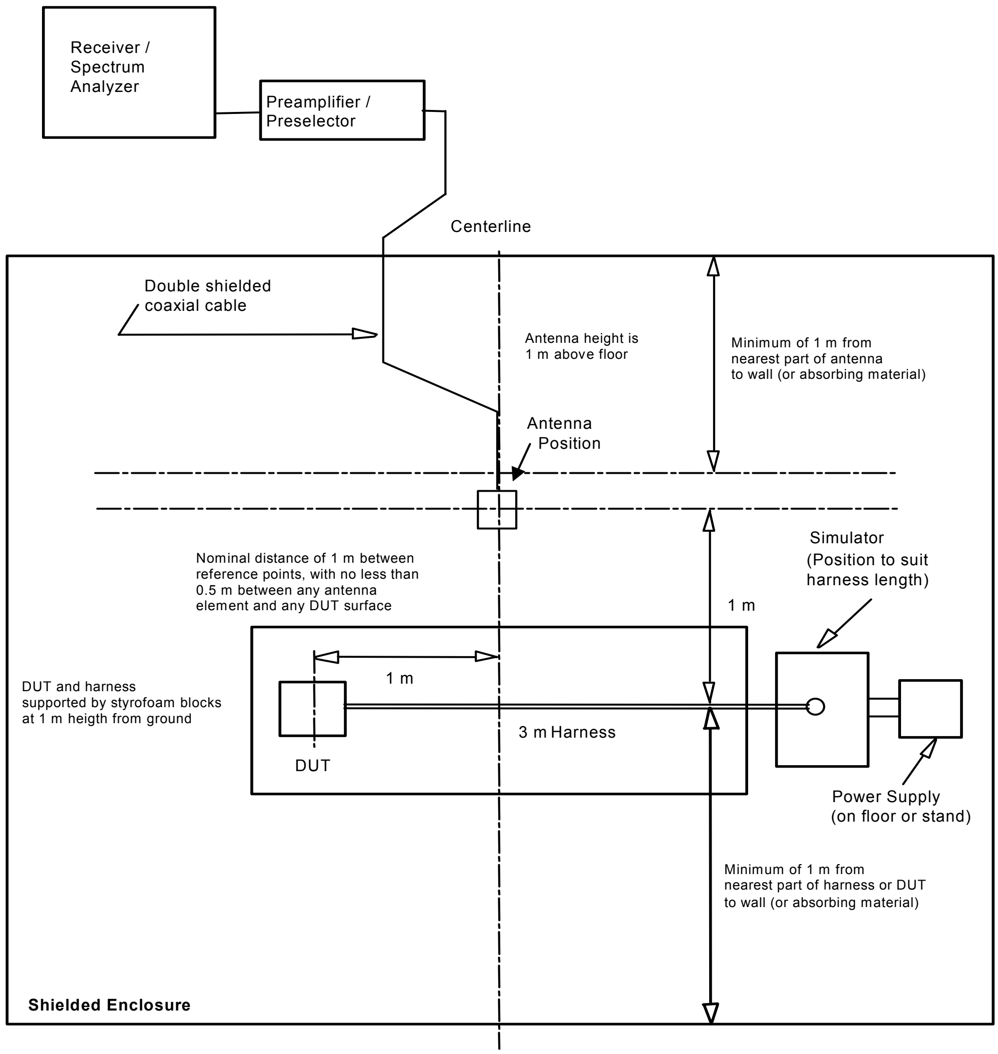


Figure 1: Test Setup for Radiated Emissions, Reverberation Chamber Test.

Report

The following elements shall be included in the test report:

- Plots for each frequency band listed in Table 8, Table 9, or a single summary plot as shown in Annex D.
- Data shall be plotted as dBμV/m versus frequency.
- The appropriate limit line shall be on each plot.

End of section 3.3.3 Radiated Emissions Reverb

3.4 Radiated Immunity (RI)

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

Determination of deviation (anomaly) thresholds 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.

All deviations that occur during immunity testing shall be recorded.

If a deviation occurs during immunity tests, the deviation will be classified according to Figure 2.

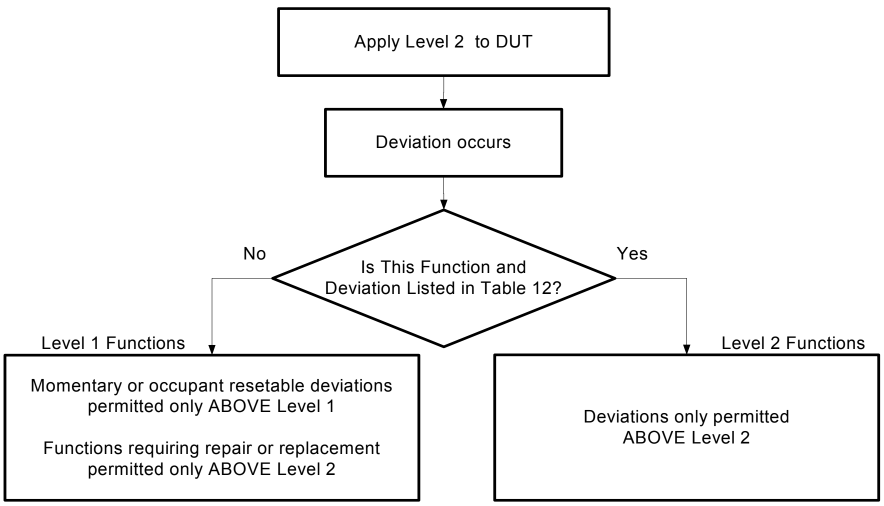


Figure 2: Performance Criteria for Radiated Immunity

Table 12 Immunity Related Functions:

a) Functions related to the direct control of the vehicle:
- by degradation or change in : e.g., engine, gear, brake, suspension, active 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 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. This implies that any of the following test methods may be used according to Paragraph 3.4.2. Anechoic Chamber Test, according to Paragraph 3.4.3 Reverberation Chamber Test, Mode Tuning; or according to Paragraph 3.4.4 Reverberation Chamber Test, Mode Stirring.

The Reverberation Chamber, Mode Stirring test method can only be used until 01 July 2005.

DUT Monitoring Instrumentation: Instrumentation and/or observation is 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 shall be measured using high impedance connections to avoid coupling to the chamber wall.

The load box / simulator shall be located within the test chamber.

The following equation shall be used for the frequency ranges in Table 13 for the following tests:

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

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

where

f_0 base frequency

k frequency index number (0,1,2,...)

n number of steps per octave

Table 13: Test frequency calculation

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

Note: Frequencies have to be rounded to at least 4 significant digits

3.4.1 RI, Bulk Current Injection (BCI)

Equipment

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

Procedure

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

- Use test frequencies according to Table 13.
- All modulation dwell time (i.e. time that RF is applied for per modulation type) shall be at least 2 s. Use calibrated injection probe method (substitution method) according to ISO 11452-4
- In the frequency range 1MHz...30 MHz ground wires that are power returns (B+/ IGN) 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...400 MHz all wires of the DUT wiring harness shall be routed inside of the injection probe, this is called Common-Mode BCI (CBCI).
- Sensors tested by themselves, that have reference grounds created by another device, and are not connected to vehicle chassis or engine block ground, shall be tested CBCI method in the frequency range from 1 MHz...30MHz
- 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 performing **DBCI.**

    Only **450 mm** and **750 mm** injection probe positions when performing **CBCI.**

- Use wiring harness length of (1700 +300/-0) mm
- 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's circuit board is positioned (50 ±5) mm above the ground plane during the bench test. If the distance between the DUT's circuit board and a vehicle ground plane is less than (50 ±5) mm, when installed in the vehicle (if known) the distance between the DUT's circuit board and the ground plane used during the bench test shall approximate that distance found in the vehicle. 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)

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

Requirements

DUT functions may only deviate above the levels according to Table 14 and Figure 3.

Table 14: 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
1...15	64...100	70...106	DBCI	CW, AM 80%
15...30	100	106	DBCI	CW, AM 80%
30...400	100...89	106...95	CBCI	CW, AM 80%

Note: For intentional AM receivers, audio deviations due to AM 80% modulation may be disregarded.

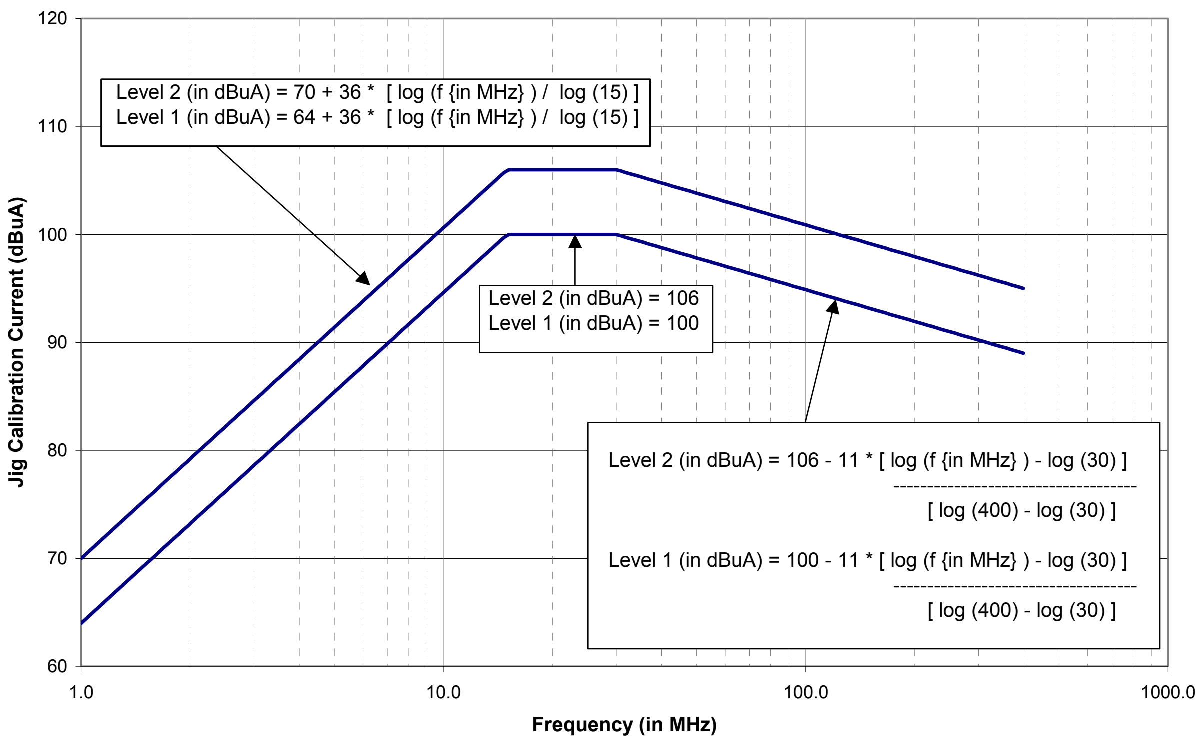


Figure 3: Requirement Levels for the Immunity to Electromagnetic Fields for Components and Subsystems measured using the CBCI and DBCI method

Report

The following elements shall be included in the test report:

- Description of the functions monitored
- Any performance deviations
- Modulation Status
- Equipment limit indication
- Appropriate requirement on the immunity threshold plot
- Tabular data and plots from the two probe positions.
- Combined tabular data and plots to form a single worst-case data set for each deviation title.

- Immunity threshold plot (calculated current in dBµA vs. frequency)
- Monitoring instrumentation and technique

At each frequency, the probe position with the lowest deviation threshold is chosen for the combined data set. Separate plots are required for each deviation.

End of section 3.4.1 Bulk Current Injection

3.4.2 RI, Anechoic Chamber

Equipment

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

- The substitution method shall be used.
- In the frequency range 400 MHz...1 GHz the field-generating device (antenna) shall be oriented as described in ISO 11452-2.
- For the frequency range 1...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.
- Horizontal and vertical polarization shall be used.
- The DUT shall be tested in a minimum of three orientations.
- For calibration and during the actual test of a DUT, forward power shall be used as reference parameter.

Procedure

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

- Use test frequencies according to Table 13.
- The load box /simulator shall be located within the test chamber.

Requirements

DUT functions may only deviate above the levels according to Table 15.

Table 15: 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…1000	50	100	CW, AM 80%
800…2000	50	70	CW, PM PRR=217 Hz, PD=0.57 ms (Note 2)
1200…1400	(Note 1)	600	Radar pulse packets PRR=300 Hz, PD=3 µs, with only 50 pulses output every 1 s (Note 2)

Note 1: Only Momentary, resettable deviations are allowed up to and including Level 2
Note 2: Pulsed field strength requirements are peak V/m (maximum RMS) levels

Report

The following elements shall be included in the test report:

- Description of the functions monitored.
- Any performance deviations.
- Modulation status.
- Maximum exposure field at each frequency.
- Equipment limit indication.
- The appropriate requirement shall be displayed on the immunity threshold plot of the DUT.
- Immunity threshold plot (field strength in V/m vs. frequency).
- Monitoring instrumentation and technique.

End of section 3.4.2 Anechoic Chamber

3.4.3 RI, Reverberation Chamber, Mode Tuning

Equipment

- Reverberation chamber: Sized large enough to test a DUT within the chamber's working volume.
- 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.
- 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.

Procedure

- Use test frequencies according to Table 13.
- The test set up is shown in Figure B.1.
- 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 13mm 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 Annex B, section B.1.1 (Field Uniformity Validation).
- Prior to collecting data, the procedures of Annex B, section B.2 (Calibration) shall be performed.
- The transmit antenna shall be in the same location as used for calibration according to Annex B.
- 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.
- The chamber input power for the electric field levels is determined via the equation:

$$Test\_Input\_Power = \left[\frac{E_{test}}{\left\langle \vec{E} \right\rangle_{24or9} \cdot \sqrt{CLF(f)}} \right]$$

where

E_{Test} = required field strength in V/m

CLF(f) = chamber loading factor from Appendix B, section B.2.vii.

$\left\langle \vec{E} \right\rangle_{24or9}$ = normalized electric field from the empty chamber calibration from Annex B, section B.1. It may be necessary to linearly interpolate (CLF and normalized electric field values) between the calibration frequency points.

Requirements

DUT functions may only deviate above the levels according to Table 16.

Table 16: 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…1000	50	100	CW, AM 80%
800...2000	50	70	CW, PM PRR=217 Hz, PD=0.57 ms
1200…1400	(Note 1)	600	Radar pulse packets PRR=300 Hz, PD=6μs, with only 50 pulses output every 1 s

Note 1: Only Momentary, resettable deviations are allowed up to and including Level 2
Note 2: Pulsed field strength requirements are peak V/m (maximum RMS) levels

Report

The following elements shall be included in the test report:

- Description of the functions monitored.
- Any performance deviations.
- Modulation status.
- Maximum exposure field at each frequency.
- Equipment limit indication.
- Number of tuner steps at each frequency.
- Immunity threshold plot (field strength in V/m vs. frequency)
- The appropriate requirement shall be displayed on the immunity threshold plot of the DUT.
- Monitoring instrumentation and technique.

End of section 3.4.3 Reverb, Mode Tuning

3.4.4 RI, Reverberation Chamber, Mode Stirring

This test method can only be used until 01 July 2005

Equipment

The test equipment shall comply with SAE J1113/27 from 400 MHz...2 GHz with the following specifications:

- The use of electric field probes is not required.

Procedure

The test procedure shall comply with SAE J1113/27 from 400 MHz...2 GHz with the following specifications:

- Use test frequencies according to Table 13.
- A 1700 (+300/-0) mm harness shall be used unless otherwise specified in the test plan.
- The stirrer revolution rate shall be (16.5 ±1) seconds per revolution.
- The DUT shall be exposed to each field level and frequency for one stirrer revolution.
- 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.

Requirements

DUT functions may only deviate above the levels according to Table 17.

Table 17: Requirement Levels for the Immunity to Electromagnetic Fields for Components and Subsystems Measured in the Reverberation Chamber

Frequency Range (MHz)	Level 1 (V/m)	Level 2 (V/m)	Modulation
400...2000	50	100	CW

Report

The following elements shall be included in the test report:

- Description of the functions monitored.
- Any performance deviations.
- Modulation status.
- Maximum exposure field at each frequency.
- Equipment limit indication.
- Indicate frequencies where receive power max/min ratio is less than 20 dB.
- Immunity threshold plot (field strength in V/m vs. frequency)
- The appropriate requirement shall be displayed on the immunity threshold plot of the DUT.
- Monitoring instrumentation and technique.

End of section 3.4.4 Reverb, Mode Stirring

3.4.5 Immunity to Power Line Magnetic Fields

Equipment

The test equipment shall comply with SAE J1113/22 with the following exceptions:

- Lower operating frequency of the equipment shall be at least 16 2/3 Hz.
- Upper operating frequency of the equipment shall be at least 180 Hz.
- Sine wave generator shall be used.

Procedure

Use test methods according to SAE J1113/22 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 seconds.
- Use the test frequencies and waveforms according to Table 18.
- The use of one or two amplifiers is allowed.
- Test three orthogonal DUT orientations.
- The harness shall be routed parallel to 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.

Requirements

DUT functions may only deviate above the requirements in Table 18.

Table 18: Magnetic Field Requirements

<table>
<tr><th>Frequency
(Hz)</th><th>Requirement
(µT RMS)</th><th>Signal Generator
Voltage Output
Waveform</th></tr>
<tr><td>16 2/3</td><td rowspan="3">50</td><td rowspan="5">Sine Wave</td></tr>
<tr><td>50</td></tr>
<tr><td>60</td></tr>
<tr><td>150</td><td rowspan="2">25</td></tr>
<tr><td>180</td></tr>
</table>

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 appropriate requirement shall be displayed on the immunity threshold plot of the DUT.

3.5 Transient, Conducted Emissions (CE) and Conducted Immunity (CI)

During Conducted Immunity testing each DUT's 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.

3.5.1 CE, Transients

Equipment

The test equipment shall comply with ISO 7637-1 and ISO 7637-2.3 (refer to Annex A)

Procedure

Use test methods in accordance with ISO/DIS 7637-2.3 (refer to Annex A) with the following specifications:

- For each type of pulse (slow or fast) the test shall be performed according to ISO/DIS 7637-2.3 (refer to Annex A), Figure 1b, but without the shunt resistor R_s .

Motors and actuators that may stall during normal operation shall, in addition, be tested in "stall" condition. The stall should not be held longer than one second. This is to prevent activation of in-line protection devices that would interrupt current to the DUT.

Transients shall be measured directly at the motor terminals for category "AX" device (electronic module that controls an inductive device) with integrated inductive device powered by B+ and/or switched B+ and controlled by an internal relay. This may require probes being placed inside the assembly.

Requirements

The voltage levels of Conducted Transients shall not exceed the levels of Table 19 when the DUT is evaluated in accordance with ISO/DIS 7637-2.3 (refer to Annex A). The conducted transient emissions requirements are established with the knowledge that they are not identical to the conducted transient immunity requirements. This difference is attributable to a) the emission measurements are obtained on the DUT side of the switch, and b) the attenuation of the DUT emission related to the switch contact arcing and the losses associated with wiring harnessing.

Table 19: Maximum Amplitude for Conducted Transients

Maximum amplitude of transient, positive polarity	+100 V
Maximum amplitude of transient, negative polarity	-150 V

Report.

The following elements shall be included in the test report:

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

End of section 3.5.1 Transient Conducted Emissions

3.5.2 CI, Transients on Power Lines

This test applies to module categories “D”, “A”, “AM”, “AX”, and “EM” (powered by battery or switched battery).

Equipment

The test equipment shall comply with ISO 7637-1 and ISO/DIS 7637-2.3 (See Annex A).

- A simulator unit to provide the inputs and outputs necessary to exercise the DUT may be necessary so that the DUT operates as if installed in the vehicle. It must duplicate the actual load and source impedances of the system accurately enough to produce results that correctly predict in-vehicle behaviour. The simulator must not change the waveform or amplitude of the injected test pulse.
- Instrumentation according to the test plan shall be used to monitor the parameters of the DUT. The negative input of the monitoring equipment must be isolated from building and earth ground.
- The monitoring instrumentation shall not disturb the DUT’s operation or alter its immunity to the injected pulse(s).

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/DIS 7637-2.3 (See Annex A) with the following specifications:

- Perform the test using pulses 1, 2a, 2b, 3a, 3b, and 4 in accordance with ISO/DIS 7637-2.3 (See Annex A).
- Pulse 1 and 2b are only applicable to switched battery lines.
- The waveform amplitude for Pulse 3a, 3b is determined from the average of the waveform peak voltages.
- 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.

Use Table 22 to determine the number of pulses or test time for pulses 1...7.

<u>Test Pulse 5b, Suppressed Load dump:</u>

Use the test setup in accordance with ISO/DIS 7637-2.3 (refer to Annex A).

- Remove the suppression network and verify that the open circuit unsuppressed load dump voltage waveform meets the specifications of Table 20.
- Connect the suppression network and verify that the open circuit suppressed voltage waveform meets the specifications of Table 20.
- Connect the 2 Ω load and verify that the suppressed loaded open circuit voltage waveform meets the specifications of Table 20.
- Replace the 2 Ω load with the DUT and begin test.

Table 20: 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 21: Two Ohm Loaded Load Dump Voltage Pulse Parameter Specifications

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

<u>Test pulse 7 (negative polarity), simulation of wiper motor switching transient:</u>

Use the test setup in Figure 4 with the following specifications:

- Use ISO pulse 2a with negative polarity.
- The supply voltage is not switched off during application of the pulse.

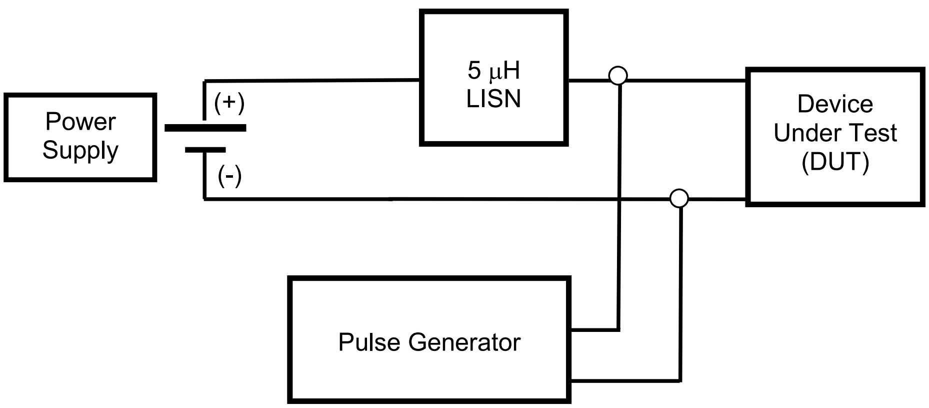


Figure 4: Setup for Pulse 7 (Simulation of wiper motor switching transient).

Requirements

DUT functions may only deviate from the designed performance above the levels according to Table 22 and Table 23 when evaluated in accordance with ISO/DIS 7637-2.3 (See Annex A).

Table 22: Requirements levels for the Immunity to Transients on Power Lines

Pulse No.	Level	Minimum Number of Pulses or Application Time	Pulse Cycle Time (min.) default	Pulse Cycle Time (max.)	Comments
1	-100 Vpeak	500 pulses	0.5 s *	5 s	One or more functions of the DUT can go beyond specified tolerance as long as all functions return within normal limits after the exposure is removed. Memory functions shall perform as designed
2a	+50 Vpeak	500 pulses	0.5 s	5 s	2Ω transient generator internal source impedance
2b	+10 Vpeak	10 pulses	0.5 s *	5 s	There shall be 10 pulses, beginning at 200 ms pulse width (t_d), then increasing pulse width by 200 ms steps until 2000 ms is achieved
3a	-150 Vpeak	10 minutes	90 ms	110 ms	
3b	+100 Vpeak	10 minutes	90 ms	110 ms	
4	See Table 23	1 pulse of each severity level	0.5 s	15 s	Voltage levels and Performance Criterion for Pulse 4 (crank pulse) see Table 23.
5b	(34 +0/-1) Vpeak	10 pulses	15 s	2 min	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=2Ω
7	-50 Vpeak	500 pulses	0.5 s	5 s	2Ω transient generator internal source impedance

* the minimum time must be long enough for the DUT's return to normal operation

Table 23: Requirements levels for the Immunity to Pulse 4: Crank Pulse

Pulse Severity	U_s	U_a	t_9	t_{11}	Performance Criterion
I	4 V	2.5V	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	

t_{10}, t_8 and t_7 as defined in ISO/DIS 7637-2.3 (See Annex A). Default value for t_7 shall be 15 ms. Default value for t_8 shall be 50 ms. All severity levels shall be tested.

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.

End of section 3.5.2 CI, Transients on 12 V Power Lines

3.5.3 CI, Coupling to I/O other than power supply lines

This test applies to module categories “A”, “AS”, “AM”, “AX”, and “EM”.

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.

Equipment.

The test equipment shall comply with ISO 7637-1 and ISO 7637-3.

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, but different than prior GMW revisions, the coupling clamp method shall route the B+ and B- outside the clamp, if not otherwise stated in the test plan.

Note: Direct pin capacitive coupling (DCC) method using a 220 pF capacitor is an alternative to the coupling clamp (refer to Section 3.5.4 for test setup and procedure).

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. Thresholding of any functional deviations is not required for this characterization.

Requirements.

DUT functions may only deviate at peak levels greater than those shown in Table 24.

Table 24 Requirements of Coupling Clamp and (Optional) Direct Pin Capacitive Coupling (DCC)

Pulse No.	Level (Vpeak) (Note 1)	Application Time	Default Time Between Pulses	(Optional) DCC Coupling Capacitance
3a	-150	10 minutes	90 ms	220 pF
3b	+100			

Note 1: Levels established into a 50 Ω load

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.

End of section 3.5.3 CI, Coupling (I/O Line)

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.

Equipment

The test equipment shall comply with ISO 7637-1 and ISO/DIS 7637-2.3 (See Annex A).

Procedure

Refer to Figure 5 for test setup.

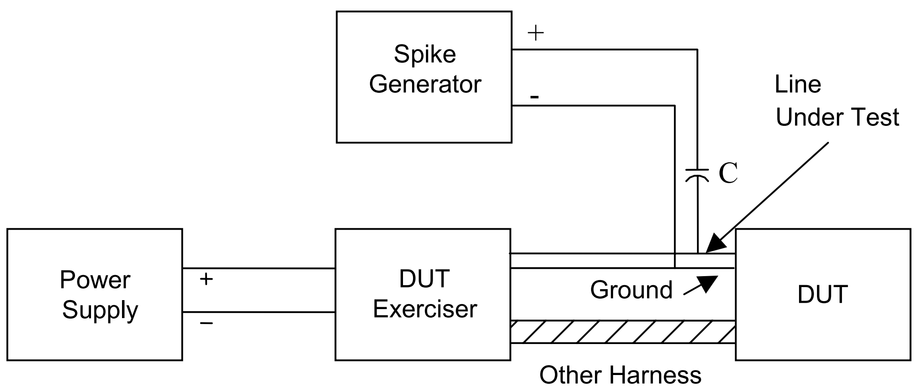


Figure 5: Setup for Direct Capacitor Coupling (DCC)

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. The generator (-) shall be directly connected to the DUT ground reference. The injection point shall be within 5 cm of the DUT connector, unless otherwise documented in the EMC Test Plan.

Sensor modules shall be subjected to repetitive voltage spikes that are capacitively coupled to the line under test, while monitoring the DUT during operation..

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 5 minutes each.

Requirements

DUT functions may only deviate at peak levels greater than those shown in Table 25.

Table 25 Requirements of Direct Capacitor Coupling to Sensor Lines

Pulse No.	Level (Vpeak) (Note 1)	Minimum Number of Pulses	Time Between Pulses	Coupling Capacitance
2a	-30	500 pulses	0.5 s	0.1 µF
	+30			
Note 1: Levels established into an open circuit Note 2: 2Ω transient generator internal source impedance				

End of section 3.5.4 CI, Transients on Power Lines

3.5.5 (Optional Test) CI, 85V Direct Capacitor Coupling

The purpose of this test is to identify potential sensitivities to excessive transients that may occur as a result of unique wiring harness coupling (e.g. cross talk).

This direct-pin transient injection test may be required on very select I/O connector pins with the DUT 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, using the experience-base of the manufacturer's EMC expert and any knowledge of the platform architecture.

Equipment.

The test equipment shall comply with ISO 7637-1 and ISO/DIS 7637-2.3 (See Annex A).

Procedure.

Refer to section 3.5.4 for test setup and procedure.

Requirements.

Report any and all functional issues.

One or more functions of the DUT can go beyond specified tolerance as long as all functions return within normal limits after the exposure is removed. Memory functions shall perform as designed when subjected to transients as defined in Table 26.

Table 26 Requirements of 85V Direct Capacitor Coupling

Pulse No.	Level	Minimum Number of Pulses	Time Between Pulses	Coupling Capacitance	Applicable Lines
2a	-85 Vpeak	10 pulses	1 s	100 nF	As specified in Test Plan
	+85 Vpeak				
Note 1: Levels established into an open circuit Note 2: 2Ω transient generator internal source impedance					

Report.

The following elements shall be included in the test report:

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

End of section 3.5.5 CI, Coupling (I/O Line)

3.6 Electrostatic Discharge

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

Equipment

The ESD simulator waveform verification shall comply with ISO 10605 with the following exceptions:

- The rise time requirement for ESD simulator characterization shall be:
  - contact discharge rise time ≤ 1ns
  - air discharge rise time ≤ 20 ns.

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.

Procedure

Use test methods according to the relevant sections of ISO 10605 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.

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

Procedure.

- Test each exposed shaft, button switch or surface of electrical / electronic devices normally accessible to an occupant inside the vehicle while seated inside the vehicle using:

  - the contact discharge method (contact discharge tip) and the 330 pF capacitor
  - the air discharge method (air discharge tip) and the 330 pF capacitor

  according to the test sequence in Table 27 for test number 1...7.
- For test number 8, test each exposed shaft, button switch or surface 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 27.

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.

Requirements.

The DUT functions may deviate according to Table 27.

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

Table 27: Requirements for Immunity to Electrostatic Discharge (Power-On Mode)

<table>
<tr><th colspan="3">Discharge (Note 1)</th><th rowspan="2">Performance Requirements Discharge</th><th rowspan="2">Network</th></tr>
<tr><th>Sequence</th><th>Type</th><th>Level (kV)</th></tr>
<tr><td>1</td><td>Air</td><td>±4</td><td>No deviations allowed</td><td rowspan="7">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</td></tr>
<tr><td>2</td><td>Contact</td><td>±4</td><td>No deviations allowed</td></tr>
<tr><td>3</td><td>Air</td><td>±6</td><td>No deviations allowed</td></tr>
<tr><td>4</td><td>Contact</td><td>±6</td><td>Momentary self-recoverable deviations allowed</td></tr>
<tr><td>5</td><td>Air</td><td>±8</td><td>Momentary self-recoverable deviations allowed</td></tr>
<tr><td>6</td><td>Contact</td><td>±8</td><td>Momentary self-recoverable deviations allowed</td></tr>
<tr><td>7</td><td>Air</td><td>±15</td><td>Momentary self-recoverable deviations allowed</td></tr>
<tr><td>8</td><td>Air</td><td>±25</td><td>Momentary self-recoverable deviations allowed</td><td>C = 150 pF,
R = 2 kΩ</td></tr>
</table>

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

End of section 3.6.1 ESD, Power-On Mode

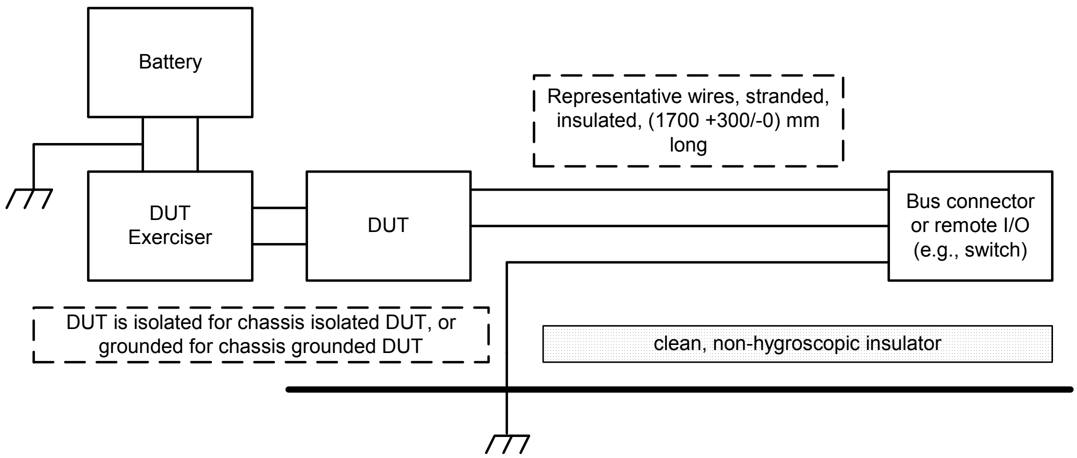
3.6.2 ESD, Remote Inputs/ Outputs

Procedure

This test method specifies a procedure for testing of components attached to data communication buses (e.g. ALDL) 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 sensor inputs, airbag control lines from mounting brackets, etc.).

The test setup shall be configured according to Figure 6.

Figure 6: ESD Setup for Remote Inputs/Output



- 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 ESD test levels, the polarity, and the order of tests shall follow Table 28. 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, it shall be tested in a live and 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.
- The ESD discharge shall be applied to the bus connector pins individually.
- When discharging to a specific pin a 2.5cm long solid core wire should be connected to extend it, if required.
- Test number 8 (25 KV) is not applicable to bus connectors.
- For communication buses the verification tool must present the maximum bus load (e.g. for Class 2 bus maximum node load is 32, therefore the bus load is R = 10.7 kΩ / 30 in parallel with C = 470 pF × 30, the nearest R and C standard values shall be used, the DUT and the DUT exerciser represent 2 bus nodes).

Note: Measuring instruments which are attached to the DUT may interfere with the test and / or result in permanent damage to the measuring instrument. As a result the use of such attachments is not permitted during the discharging events.

Requirements.

The DUT functions may deviate according to Table 28.

Table 28: Requirements for Immunity to Electrostatic Discharge of Remote Inputs/Outputs

Discharge (Note 1)			Performance Requirements Discharge	Network
Sequence	Type	Level (kV)		
1	Air	±4	No deviations allowed	C = 330 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

End of section 3.6.2 ESD, Remote I/O

3.6.3 ESD, Handling of Devices

Procedure

Test each connector pin (recessed pins in metalized connectors are exempt), case, button, switch, display, case screw and case opening of the DUT that is accessible during handling following these steps;

- The GMW 3103 EMC Test Plan (Appendix B) may specify DUT's other than those used for powered mode testing
- 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.

Requirements

The DUT functions may deviate according to Table 29.

Table 29: Requirements for Immunity to Electrostatic Discharge (Handling of Devices)

Discharge (Note 1)			Performance Requirements Discharge	Network
Sequence	Type	Level (kV)		
1	Contact	±4	No deviations allowed	C = 150 pF, R = 2 kΩ
2	Contact	±6	No deviations allowed	
3	Air	±8	No deviations allowed	

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

End of section 3.6.3 ESD, Handling of devices

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

5 Notes

5.1 Acronyms, Abbreviations and Symbols.

ACF	Antenna Calibration Factor
AF	Antenna Factor
ALDL	Assembly Line Data Link
ALSE	Absorber Lined Shielded Enclosure
AV	Average
CAN	Controller Area Network
CBCI	Common Mode Bulk Current Injection
CCF	Chamber Calibration Factor
CE	Conducted Emissions
CI	Conducted Immunity
CLF	Chamber Loading Factor
CTS	Component Technical Specification
DAB	Digital Audio Broadcast
DBCI	Differential Mode Bulk Current Injection
DC	Direct Current
DUT	Device under Test
EMC	Electromagnetic Compatibility
ESD	Electrostatic Discharge
GM	General Motors
GMW	General Motors Worldwide
GPS	Global Positioning System
I/O	Input/Output
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
ITDC	International Technical Development Center
LISN	Line Impedance Simulation Network
LW	Long Wave
PK	Peak
PWM	Pulse Width Modulated
QP	Quasi-Peak
RBW	Resolution Bandwidth
RFA	Remote Function Actuation/Actuator
RMS	Root Mean Square
SAE	Society of Automotive Engineers
SSTS	Subsystem Technical Specification

TPMS	Tire Pressure Monitoring System	VTS	Vehicle Technical Specification

6 Coding System

This specification shall be referenced in other documents, drawings, VTS, CTS, etc. as follows: GMW3097

Where:

GMW Validation Area (GM Worldwide) and,

3097 Sequential number

Class: General Specification

Type: All Vehicle

Category: Electrical Architecture

Example Wording: “Requirements to GMW3097”

7 Release and Revisions

7.1 Release

This specification was first approved in APR 1999. It has been prepared by the GM Global EMC Committee.

7.2 Revisions

Rev.	Approval Date	Description (Org.)
A	Apr 1999	New, was also called "revision 1" (ITDC)
B	Mar 2000	Editorial, was also called "revision1" (GMNA)
C	Oct 2000	Reworked, was also called "revision 2" (ITDC)
D	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)
E	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)
G	Feb 2004	Publication Feb 2004. Editorial revision, also called “revision 4”, typographical errors corrected

Annex A: ISO/DIS 7637-2.3, 18SEP2002

This annex uses the same paragraph numbering scheme as in ISO/DIS 7637-2.3. Please disregard any mention to Annex A or Annex F.

4.2 Test temperature and test voltage

The ambient temperature during the test shall be (23 ± 5) °C.
The test voltages shall be as shown in table 1 unless other values are agreed upon by the users of this part of ISO 7637, in which case such values shall be documented in the test reports.

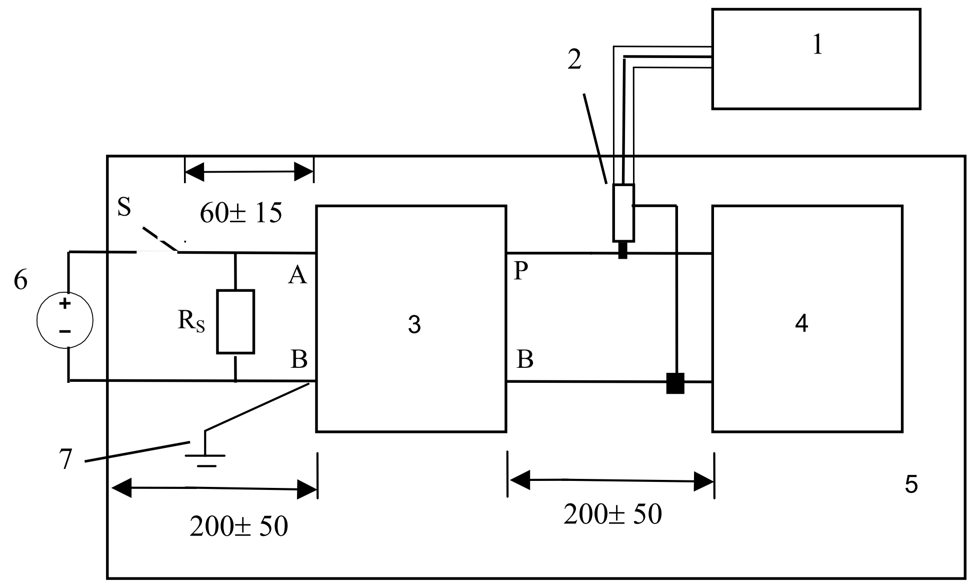
Table 1 – Test voltages

Test voltage	12 V system	24 V system
U_A	13,5 ± 0,5 V	27 ± 1 V
U_B	12 ± 0,2 V	24 ± 0,4 V

4.3 Voltage transient emissions test

This clause defines a test procedure to evaluate automotive electrical and electronic components for conducted emissions of transients along battery fed or switched supply lines of a Device Under Test (DUT). A device under test which is considered a potential source of conducted disturbances should be tested according to the procedure described in this clause.
Care shall be taken to ensure that the surrounding electromagnetic environment does not interfere with the measurement set-up.
Voltage transients from the disturbance source, the device under test, are measured using the artificial network to standardise the impedance loading on the device under test (see 4.1). The disturbance source is connected via the artificial network to the shunt resistor R_S (see 4.2), the switch *S* (see 4.3) and the power supply (see 4.4), as given in figure 1a or 1b.
All wiring connections between artificial network, switch, and the device under test shall be spaced $\left(50\ ^{+10}_{\ \ 0}\right)$ mm above the metal ground plane.
The cable sizes shall be chosen in accordance with the real situation in the vehicle, i.e. the wiring shall be capable of handling the operating current of the device under test, and as agreed between vehicle manufacturer and supplier.
If no requirements are specified in the test plan, then the device under test shall be placed on a non-conductive material $\left(50\ ^{+10}_{\ \ 0}\right)$ mm above the ground plane.
The disturbance voltage is measured as close to the device under test terminals as possible (see figure 1a or 1b), using a voltage probe (see 4.5.2) and an oscilloscope (see 4.5.1) or waveform acquisition equipment (see 4.5.3).
Repetitive transients are measured with the switch *S* closed. If the transient is caused by a supply disconnection, measurement is started at the moment of opening switch *S*.

Dimensions in millimeters



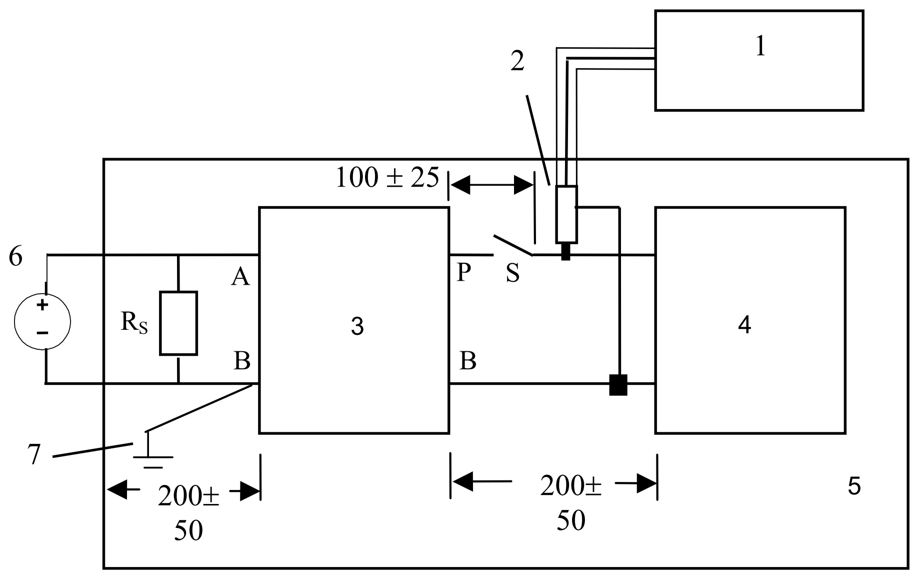
Drawing not to scale

Key
1 Oscilloscope or equivalent
2 Voltage probe
3 Artificial network
4 Device under test (source of transient)
5 Ground plane
6 Power supply
7 Ground connection; length < 100 mm

NOTE A, B, P see Figure 3

Figure 1a - Transient emission test set-up to measure slow pulses (ms-range or slower)

Dimensions in millimeters



Drawing not to scale

Key
1 Oscilloscope or equivalent
2 Voltage probe
3 Artificial network
4 Device under test (source of transient)
5 Ground plane
6 Power supply
7 Ground connection; length < 100 mm

NOTE A, B, P see Figure 3

Figure 1b - Transient emission test set-up to measure fast pulses (ns to μs range)

Device under test operating conditions of particular interest in the measurements are the turn on, the turn off, and the exercising of the various operating modes of the device under test. Exact operating conditions of the device under test must be specified in the test plan.

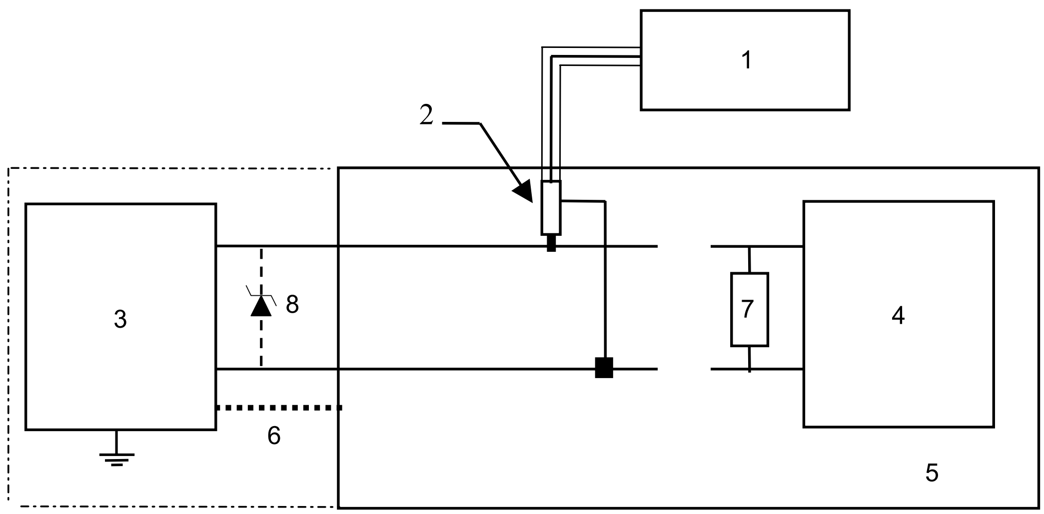
The sampling rate and trigger level shall be selected to capture a waveform displaying the complete duration of the transient, and with sufficient resolution, to display the highest positive and negative portions of the transient.

Utilizing the proper sampling rate and trigger level, the voltage amplitude shall be recorded by actuating the device under test according to the test plan. Other transient parameters, such as rise time, fall time, transient duration, etc. may also be recorded. Unless otherwise specified, ten waveform acquisitions are necessary. It is necessary to only report the waveforms with highest positive and negative amplitude (with their associated parameters).

All pertinent information and test results shall be reported. If required per test plan, include transient evaluation results with respect to the performance objective as specified in the test plan.

4.4 Transient immunity test

The test set-up for transient immunity measurements of electrical/ electronic devices is given in Figure 2a.



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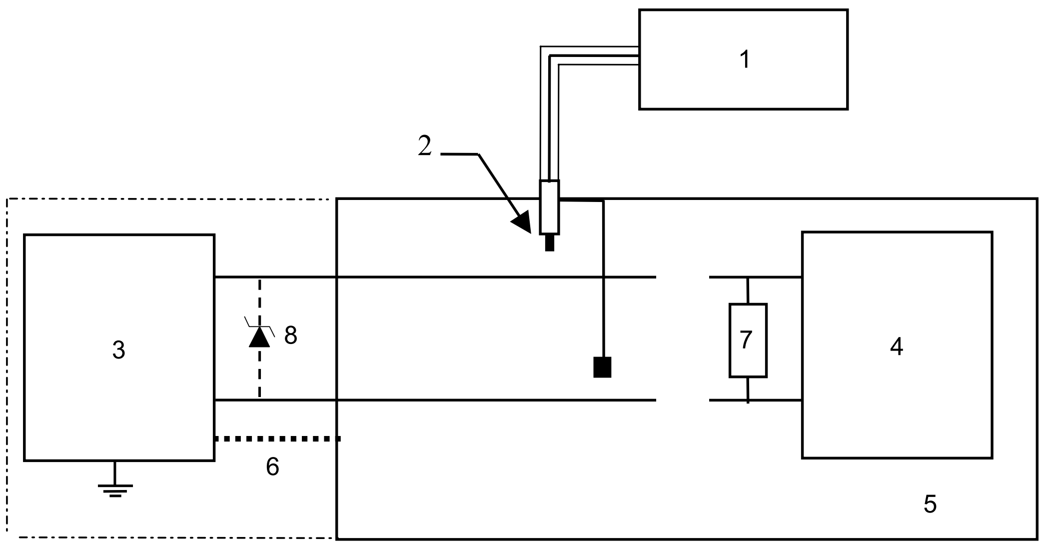
Key

1 Oscilloscope or equivalent
2 Voltage probe
3 Test pulse generator with internal power supply resistance R_i
4 Device under test
5 Ground plane
6 Ground connection. Maximum length for test pulse 3 is 100 mm
7 Optional resistor (R_V) to simulate vehicle system loading for load dump test pulse 5a and 5b only. If used, the value of (R_V) shall be specified in the test plan (typical value 0,7 Ω to 40 Ω)
8 Optional diode bridge for simulation of load dump waveform for alternator with centralized load dump suppression for pulse 5b only (see figure 2c)

Figure 2a - Transient immunity test set-up - Pulse adjustment

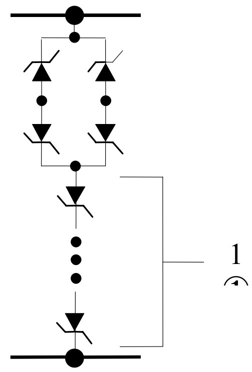


Drawing not to scale

Key

1 Oscilloscope or equivalent
2 Voltage probe
3 Test pulse generator with internal power supply resistance R_i
4 Device under test
5 Ground plane
6 Ground connection. Maximum length for test pulse 3 is 100 mm
7 Optional resistor (R_V) to simulate vehicle system loading for load dump test pulse 5a and 5b only. If used, the value of (R_V) shall be specified in the test plan (typical value 0,7 Ω to 40 Ω)
8 Optional diode bridge for simulation of load dump waveform for alternator with centralized load dump suppression for pulse 5b only (see figure 2c)

Figure 2b - Transient immunity test set-up - Pulse injection



Key

1 Add forward biased diodes as required to achieve maximum open-circuit (suppressed) voltage

Figure 2c - Example of suppression diode bridge for test pulse 5b only

Figure 2 – Transient immunity test set-up

For test pulses 3a and 3b, the leads between the terminals of the test pulse generator and the device under test shall be laid out in a straight parallel line in a height of $\left(50\ {}^{+10}_{\ \ 0}\right)$ mm above the metallic ground plane and shall have a length of $(0{,}5 \pm 0{,}1)$m.
The test pulse generator (see 4.6) is set up to provide the specific pulse polarity, amplitude, duration and resistance with device under test and optional resistance R_V disconnected (see figure 2a). (The appropriate values are selected from Annex A). Next, the device under test is connected to the generator, see figure 2b, while the oscilloscope is disconnected.

Depending on the real conditions, the function of the device under test may be evaluated during and/or after the application of the test pulses.

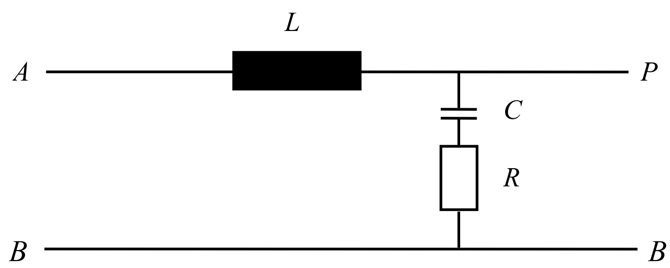
For correct generation of the required test pulses it may be necessary to switch the power supply on and off. The switching can be performed by the test pulse generator if the power supply is integral to it.
A way to simulate the waveform of an alternator with centralized load dump suppression (figure 12), is to connect a suppression diode (or diode bridge) across the output terminals of the test pulse generator (figure 2a and 2b). Since a single diode will generally have part-to-part variation and may not be able to handle the large alternator currents, the use of a bridge arrangement (an example is shown in figure 2c) is recommended. The same generator shall be used for test pulses 5a and 5b.

The suppression diodes and the suppressed voltage levels (clamping voltage) used by different car manufacturers are not standard. The supplier (parts manufacturers) must, therefore, obtain the diode and clamping voltage specification information from the manufacturer to be able to perform this test. The single diodes are added to the diode bridge as needed to provide the specified clamping voltage.

5 Test instrument description and specifications

5.1 Artificial network

The artificial network is used as a reference standard in the laboratory in place of the impedance of the vehicle wiring harness in order to determine the behaviour of equipment and electrical and electronic devices. An example of a schematic diagram is given in figure 3.



Key

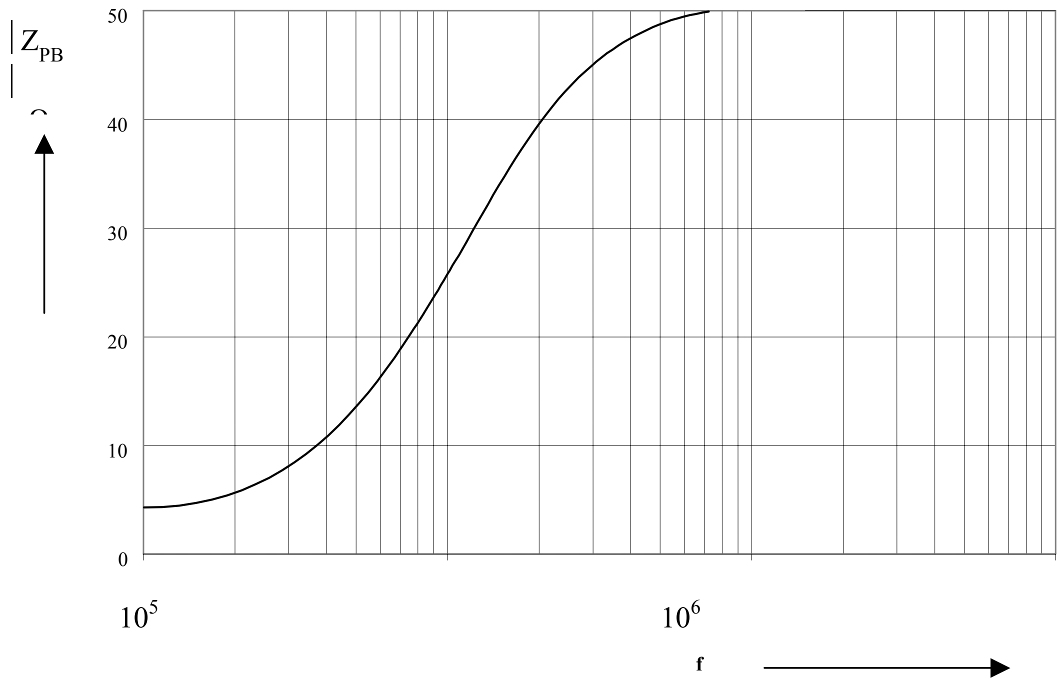
A Power supply terminal
B Common terminal (may be grounded)
C Capacitor
L Inductance
P Terminal for the device under test
R Resistor

Figure 3 - Example of a schematic diagram of artificial network

The artificial network shall be able to withstand a continuous load corresponding to the requirements of the device under test.

The resulting values of impedance $|Z_{PB}|$, measured between the terminals *P* and *B* while terminals *A* and *B* are short-circuited, are given in figure 4 as a function of frequency assuming ideal electric components. In reality, the impedance of an artificial network shall not deviate more than 10 % from the curve given in figure 4.

The main characteristics of the components are as follows: inductance: L = 5 μH (air-core winding);
internal resistance between terminals *P* and *A*: < 5 mΩ;
capacitor: C = 0,1 μF for working voltages of 200 V ac and 1500 V dc;
resistor: R = 50 Ω.



Key

| Z_{PB} | Impedance (Ω)

f Frequency (Hz)

Figure 4 - Impedance | Z_{PB} | as a function of frequency from 100 kHz to 100 MHz (AB short-circuited)

If the artificial network has a metal enclosure, it shall be placed flat on the ground plane and the ground terminal on the power source end shall be connected to the ground plane as shown in figures 1a and 1b.

5.2 Shunt resistor R_S

The shunt resistor R_S (see figure 1) simulates the dc resistance of other vehicle devices that are connected in parallel to the device under test and are not disconnected from it by the ignition switch. R_S is selected to correspond to the resistance measured on the wiring harness between the disconnected ignition switch terminal and ground, with the switch off, and shall be specified by the vehicle manufacturer. In the absence of any specification, a value of R_S = 40 Ω shall be used. If a wire-wound resistor is used, the winding shall be bifilar (i.e. with a minimum reactive component).

NOTE: To simulate the worst-case condition, R_S may be switched off.

5.3 Switch S

The switching device S can be located on either side of the artificial network as shown in figure 1 depending on the actual application. For the measurement of fast transients (t_d ≈ µs range), the switch on the device under test side of the artificial network has to be actuated.
During the test, only one of the switching devices in figure 1 shall be actuated (the contact of the other switching device shall be closed). The selection of the switching device shall be specified in the test plan prior to the test and documented in the test report.
As the switch S significantly influences the disturbance transient characteristics, the recommended switching devices are described below:

- For the measurement of high voltage transients (with amplitudes over 400 V), the switching device is recommended to be a standard production switch that is used in the vehicle with the device under test. If such a device is not available, an automotive relay with the following characteristics shall be used:

  - contact rating: I = 30 A, continuous, resistive load ;
  - high purity silver contact material ;
  - no suppression across relay contact;
  - single/double position contact electrically insulated from the coil circuit ;
  - coil with transient suppression.

The switching relay shall be replaced if significant contact degradation occurs.

- An unequivocal assessment of the disturbance is only possible if a switch with reproducible properties is used. For this purpose, an electronic switch is proposed. It is probable that amplitudes of disturbance are higher than those normally encountered with conventional switches (arcing). This shall be taken into account when evaluating test results. The electronic switch is very appropriate for controlling the function of suppressors used. For the measurement of lower voltage transients (with amplitudes less than 400 V) such as those produced by sources with transient suppressions, the switching device is recommended to be an electronic switch with the following characteristics:

  - maximum voltage: $U_{max.}$ = 400 V at 25 A;
  - maximum current: $I_{max.}$ = 25 A continuously, 100 A for $\Delta t \leq 1$ s;
  - voltage drop: $\Delta U \leq 1$ V at 25 A;
  - test voltages: U_{A1} = 13,5 V, U_{A2} = 27 V;
  - switching time: Δt_S = 300 ns $\pm$ 20 % with device under test;
  - R = 0,6 Ω, L = 50 µH (1 kHz);
  - shunt resistor: R_S = 10 Ω, 20 Ω, 40 Ω, and connection for external resistors;
  - trigger: internal and external;
  - voltage probe: 1: 100.

The switch shall withstand short-circuiting.

An artificial network according to 4.1 and figures 3 and 4 shall be implemented, but it shall be possible to switch it off (50 Ω artificial network is defined up to 100 MHz).

5.4 Power supply
The continuous supply source shall have an internal resistance R_i less than 0,01 Ω dc and an internal impedance $Z_i = R_i$ for frequencies less than 400 Hz. The output voltage shall not deviate more than 1 V from 0 to maximum load (including inrush current) and shall recover 63 % of its maximum excursion within 100 µs. The superimposed ripple voltage, U_r, shall not exceed 0,2 V peak-to-peak and have a minimum frequency of 400 Hz.
If a standard power supply (with sufficient current capacity) is used to simulate the battery, it is important that the low internal impedance of the battery is also simulated.

When a battery is used, a charging source may be needed to achieve the specified reference levels (13,5 V and 27 V, respectively).

5.5 Measurement instrumentation
5.5.1 Oscilloscope
The use of a digitizing oscilloscope (minimum single sweep sampling rate of 2 GHz per second and 400 MHz bandwidth with input sensitivity: at least 5 mV/division) is preferred. If a digitizing oscilloscope is not available, an analogue storage oscilloscope may be used.

For an analogue storage oscilloscope, the following minimum specifications apply:

- bandwidth: dc to at least 400 MHz;
- writing speed: at least 100 cm/µs;
- input sensitivity: at least 5 mV/division.

The recording may be made with an oscilloscope camera or any other appropriate recording device.

5.5.2 Voltage probe
Characteristics of the voltage probe are:

- attenuation: 100/1 ;
- maximum input voltage of at least 1 kV ;
- input impedance Z and capacitance C, according to table 2 ;
- maximum length of the probe cable of 3 m ;
- maximum length of the probe ground of 0,13 m.

The lengths will influence the measurement results and shall be stated in the test report.

Table 2 - Voltage probe parameters

f MHz	***Z*** kΩ	***C*** pF
1	> 40	< 4
10	> 4	< 4
100	> 0,4	< 4

5.5.3 Waveform acquisition equipment

Equipment that is capable of acquiring fast rise time transient waveforms can be used instead of an oscilloscope.

5.6 Test pulse generator for immunity testing

The test pulse generator shall be capable of producing the open circuit test pulses described in 4.6.1 to 4.6.5 at the maximum value of $|U_s|$. U_s shall be adjustable within the limits given in tables 3 to 9.
The peak voltage U_s shall be adjusted to the test levels specified in Annex A with tolerances of + 10 % and 0 %. The timing (t) tolerances and internal resistance (R_i) tolerance shall be ± 20 % unless otherwise specified.
A verification procedure for the generator performance and tolerances is described in Annex D.
Recommended values for the evaluation of immunity of devices can be chosen from tables A.1a and A.1b.

5.6.1 Test pulse 1

This test is a simulation of transients due to supply disconnection from inductive loads; it applies to a device under test if, as used in the vehicle, it remains connected directly in parallel with an inductive load (see F.2.1 in annex F).

The pulse shape is given in figure 5.

The parameters are given in table 3.

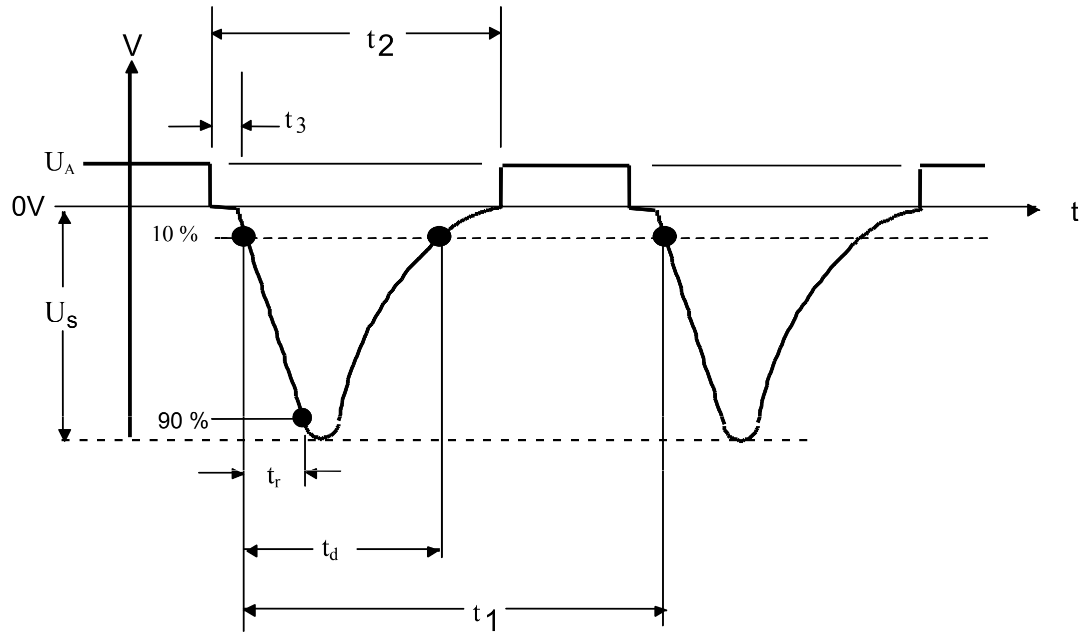


Figure 5 - Test pulse 1

Table 3 – Parameters for test pulse 1

Parameters	12 V system	24 V system
U_s	- 75 V to - 100 V	- 450 V to - 600 V
R_i	10 Ω	50 Ω
t_d	2 ms	1 ms
t_r	$(1\ ^{0}_{-0,5})$ µs	$(3\ ^{0}_{-1,5})$ µs
t_1 1)	0,5 s to 5 s	
t_2	200 ms	
t_3 2)	< 100 µs	

1) t_1 shall be chosen such that the device under test is correctly initialised before the application of the next pulse.
2) t_3 is the smallest possible time necessary between the disconnection of the supply source and the application of the pulse.

5.6.2 Test pulses 2a and 2 b

Pulse 2a simulates transients due to sudden interruption of currents in a device connected in parallel with the device under test due to the inductance of the wiring harness.(see in F.2.2 Annex F).
Pulse 2b simulates transients from dc motors acting as generators after the ignition is switched off (see in F.2.2 Annex F).

The pulse shapes and parameters for these test pulses are given in figures 8 and 9, and tables 6 and 7, respectively.

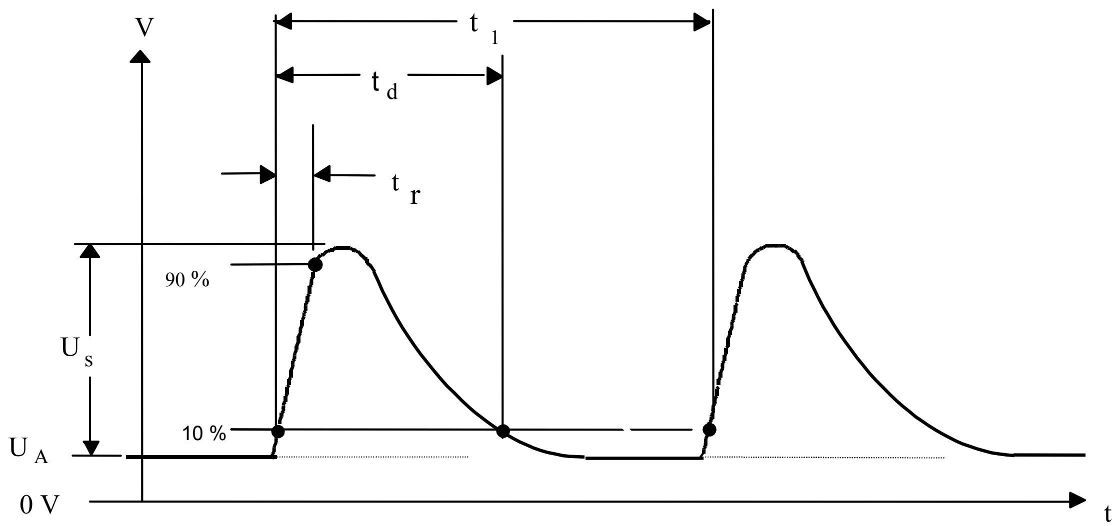


Figure 6 - Test pulse 2a

The pulse shapes are given in figures 6 and 7. The parameters are given in tables 4 and 5.

Table 4 – Parameters for test pulse 2a

Parameters	12 V system	24 V system
U_s	+ 37 V to + 50 V	
R_i	2 Ω	
t_d	0,05 ms	
t_r	$(1\ ^{0}_{-0,5})$ µs	
t_1 1)	0,2 s to 5 s	
1) The repetition time t_1 can be short depending on the switching. The use of a short repetition time reduces the test time.		

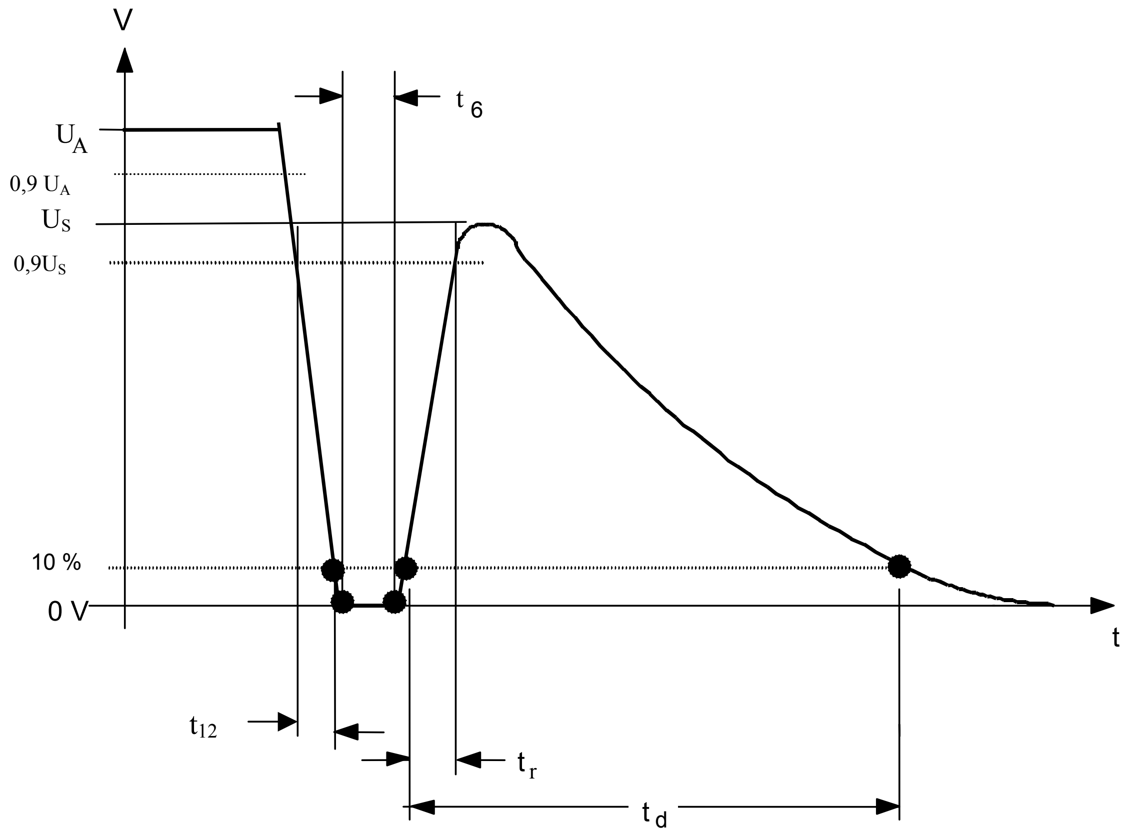


Figure 7 - Test pulse 2b

Table 5 – Parameters for test pulse 2b

Parameters	12 V system	24 V system
U_s	10 V	20 V
R_i	0 Ω to 0,05 Ω	
t_d	0,2 s to 2 s	
t_{12}	1 ms ± 0,5 ms	
t_r	1 ms ± 0,5 ms	
t_6	1 ms ± 0,5 ms	

5.6.3 Test pulses 3a and 3b

These test pulses are a simulation of transients, which occur as a result of the switching processes. The characteristics of these transients are influenced by distributed capacitance and inductance of the wiring harness (see in F.2.3 Annex F).

The pulse shapes and parameters for these test pulses are given in figures 8 and 9, and tables 6 and 7, respectively.

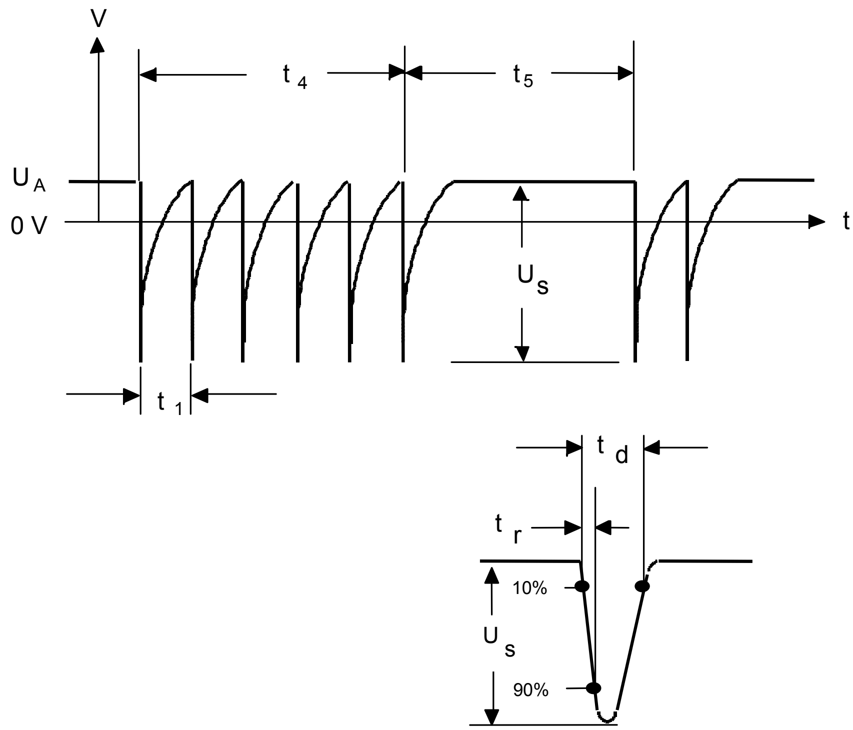


Figure 8 – Test pulse 3a

Table 6 - Parameters for test pulse 3a

Parameters	12 V system	24 V system
U_s	- 112 V to - 150 V	- 150 V to - 200 V
R_i	50 Ω	
t_d	$(0,1\ ^{+0,1}_{\ 0})$ µs	
t_r	5 ns ± 1,5 ns	
t_1	100 µs	
t_4	10 ms	
t_5	90 ms	

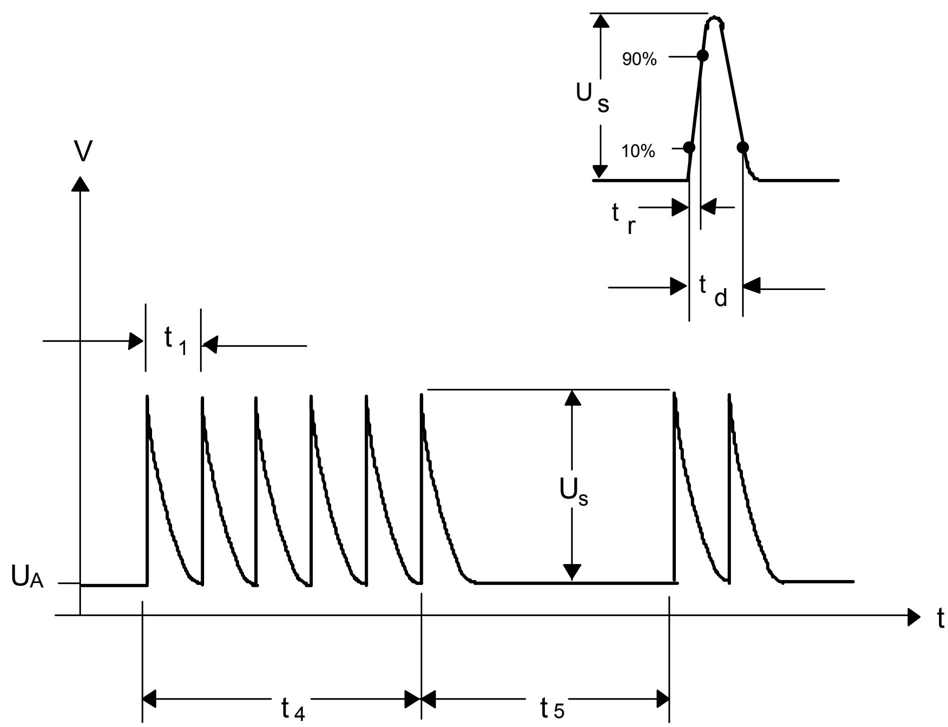


Figure 9 - Test pulse 3b

Table 7 – Parameters for test pulse 3b

Parameters	12 V system	24 V system
U_s	+ 75 V to + 100 V	+ 150 V to + 200 V
R_i	50 Ω	
t_d	$(0{,}1\ ^{+0{,}1}_{\ \ 0})$ µs	
t_r	5 ns ± 1,5 ns	
t_1	100 µs	
t_4	10 ms	
t_5	90 ms	

5.6.4 Test pulse 4

This pulse simulates supply voltage reduction caused by energising the starter-motor circuits of internal combustion engines, excluding spikes associated with starting (see in F.2.4 Annex F).
The pulse shape and parameters are given in figure 10 and table 8.

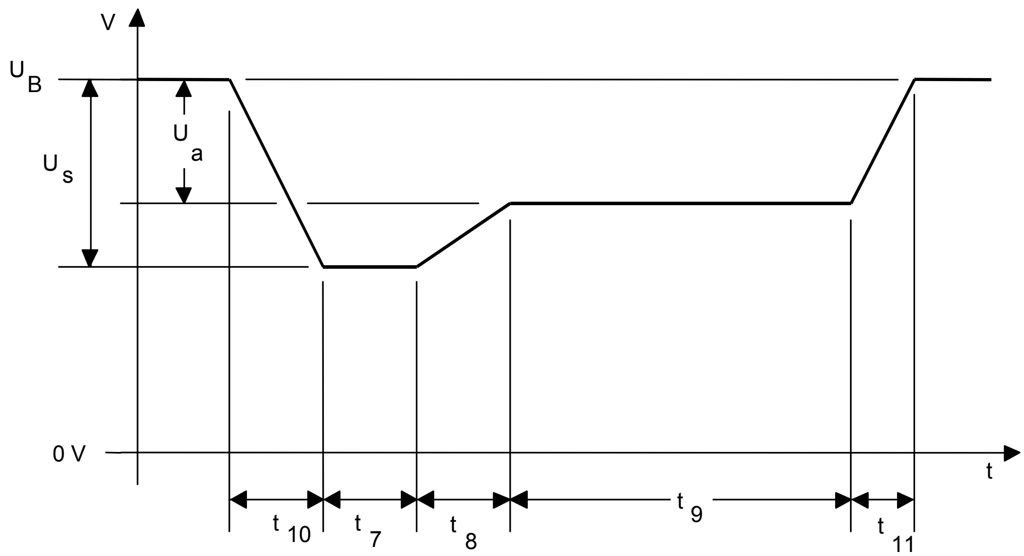


Figure 10 – Test pulse 4

Table 8 – Parameters for test pulse 4

Parameters	**12 V system**	**24 V system**
U_s	- 6 V to - 7 V	- 12 V to - 16 V
U_a	- 2,5 V to - 6 V with $\lvert U_a \rvert \leq \lvert U_s \rvert$	- 5 V to - 12 V with $\lvert U_a \rvert \leq \lvert U_s \rvert$
R_i	0 Ω to 0,02 Ω	
t_7	15 ms to 40 ms [1)]	50 ms to 100 ms [1)]
t_8	≤ 50 ms	
t_9	0,5 s to 20 s [1)]	
t_{10}	5 ms	10 ms
t_{11}	5 ms to 100 ms [2)]	10 ms to 100 ms [3)]

1) The value used should be agreed between the vehicle manufacturer and the equipment supplier to suit the proposed application.

2) t_{11} = 5 ms is typical of the case when engine starts at the end of the cranking period, while t_{11} = 100 ms is typical of the case when the engine does not start.

3) t_{11} = 10 ms is typical of the case when engine starts at the end of the cranking period, while t_{11} = 100 ms is typical of the case when the engine does not start.

5.6.5 Test pulses 5a and 5b

This test is a simulation of load dump transient occurring in the event of a discharged battery being disconnected while the alternator is generating charging current with other loads remaining on the alternator circuit at this moment; the load dump amplitude depends on the alternator speed and on the level of the alternator field excitation at the moment of the battery being disconnected. The load dump pulse duration depends essentially on the time constant of the field excitation circuit and on the pulse amplitude (see in F.2.5 Annex F). In most new alternators, the load dump amplitude is suppressed (clamped) by the addition of the limiting diodes.

Load dump may occur on account of a battery being disconnected resulting from cable corrosion, poor connection or the battery being disconnected intentionally while the engine is running.

The pulse shape and parameters for an alternator with no centralized load dump suppression (pulse 5a) are given in figure 11 and table 9. The pulse shape and parameters for an alternator with centralized load dump suppression (pulse 5b) are given in figure 12 and table 10.

The decreasing portion of the pulse follows an exponential curve which would theoretically decrease to 0 V, but is interrupted at U_A.

The following general considerations of the dynamic behavior of alternators during load dump apply:

a) The internal resistance of an alternator, in the case of load dump, is mainly a function of alternator rotational speed and excitation current.

b) The internal resistance, R_i,of the load dump test pulse generator shall be obtained from the following relationship:

$$R_i = \frac{10 \times U_{nom} \times N_{act}}{0{,}8 \times I_{rated} \times 12\ 000\ \text{min}^{-1}}$$

where

U_{nom} is the specified voltage of the alternator ;

I_{rated} is the specified current at an alternator speed of 6 000 min^{-1} (as given in ISO 8854);

N_{act} is the actual alternator speed, in reciprocal minutes.

c) The pulse is determined by the peak voltage U_s, the clamped voltage U_s *, the internal resistance R_i, and the pulse duration t_d ; in all cases small values of U_s are correlated with small values of R_i and t_d, and high values of U_s with high values of R_i and t_d.

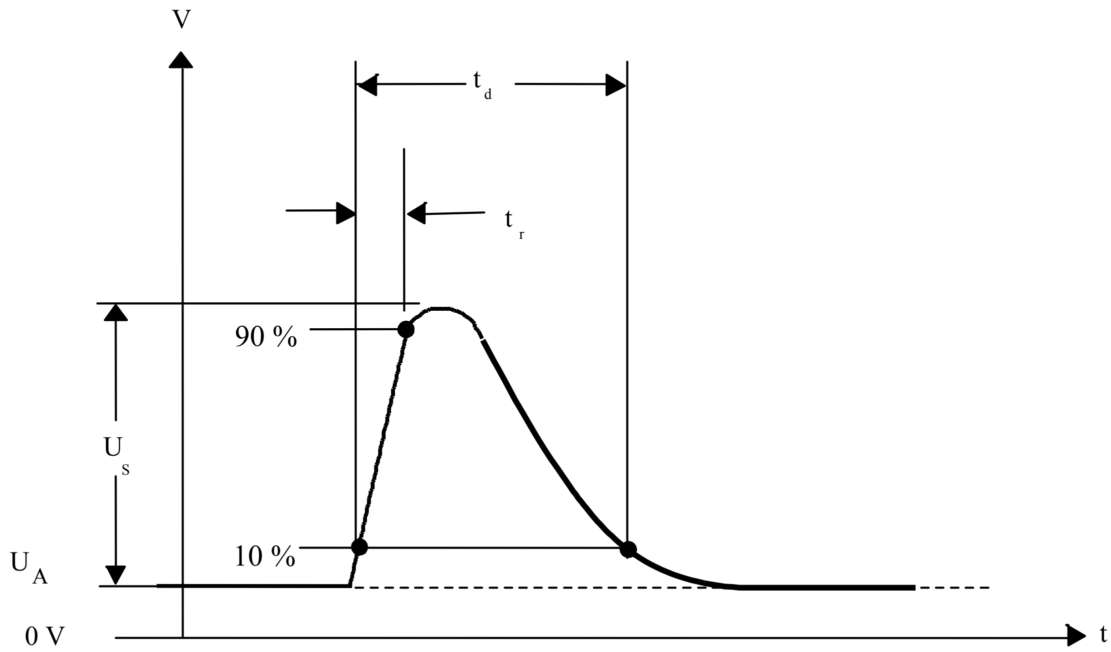
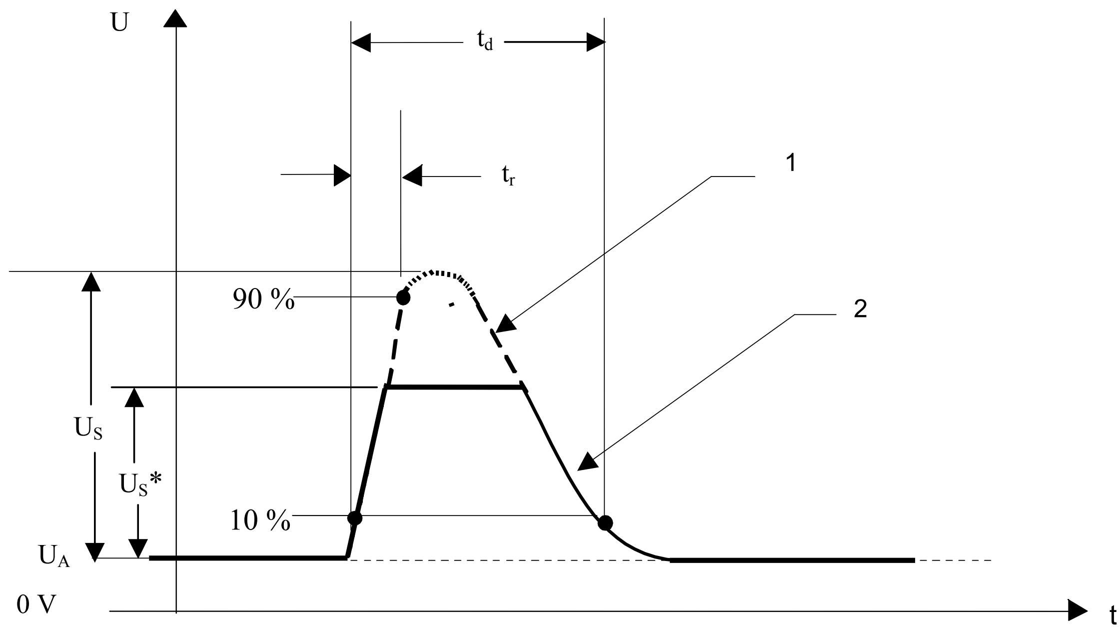


Figure 11 - Test pulse 5a

Table 9 – Parameters for test pulse 5a

Parameters	12 V system	24 V system
U_S	65 V to 87 V	123 V to 174 V
R_i	0,5 Ω to 4 Ω	1 Ω to 8 Ω
t_d	40 ms to 400 ms	100 ms to 350 ms
t_r	$(10\,^{0}_{-5})$ ms	



Key

1 Unsuppressed

2 Suppressed

Figure 12 - Test pulse 5b

Table 10 – Parameters for test pulse 5b

Parameters	12 V system	24 V system
U_S	65 V to 87 V	123 V to 174 V
U_S*	As specified by customer	
t_d	Same as unsuppressed value	

Annex D of 7637-2.3
(normative)

Test pulse generator verification procedure

D.1 Scope

The purpose of this annex is to provide a method for the verification of the output characteristics of the test pulse generator.

D.2 General

See 4.5 for measurement instrumentation requirements.

The verification measurements described in D.3 shall be performed under two different loading conditions to determine the behavior of the test pulse generator:

- Under no load condition;
- Under matched load conditions.

D.3 Pulse verification

The generator must be verified to ensure compliance to the parameters listed below for both open circuit and loaded conditions. The energy content may influence significantly the test results. Within the test report the

energy of the actual used pulses must be listed (see Annex F for example of methods for determining pulse energy)
The U_A and U_B for this verification procedure are 0 volts
Care shall be taken for the selection of the resistors. They shall have sufficient power dissipation for both pulse and dc supply rating. Additionally they shall be non-inductive. The tolerance of the matching resistor shall be ± 1%.
The source impedance shall be selected to be equal to the load resistance defined for each test pulse.

D.3.1 Test pulse 1

D.3.1.1 Test pulse 1 (12 V system)

Table D.1 – Test pulse 1 (12 V system)

Test pulse 1	V_s	t_r	t_d
No load	- 100 V ± 10 V	$\left(1\ {}^{0}_{-\,0,5}\right)$ µs	2 000 µs ± 400 µs
10 Ω load	- 50 V ± 10 V	-	1 500 µs ± 300 µs

D.3.1.2 Test pulse 1 (24 V system)

Table D.2 – Test pulse 1 (24 V system)

Test pulse 1	V_s	t_r	t_d
No load	- 600 V ± 60 V	$\left(3\ {}^{0}_{-\,1,5}\right)$ µs	1 000 µs ± 200 µs
50 Ω load	- 300 V ± 30 V	-	1 000 µs ± 200 µs

D.3.2 Test pulse 2
D.3.2.1 Test pulse 2a (12 V and 24 V system)

Table D.3 – Test pulse 2a (12 V and 24 V system)

Test pulse 2a	V_s	t_r	t_d
No load	+ 50 V ± 5 V	$\left(1\ {}^{0}_{-\,0,5}\right)$ µs	50 µs ± 10 µs
2 Ω load	+ 25 V ± 5 V	-	12 µs ± 2,4 µs

D.3.2.2 Test pulse 2b (12 V and 24 V system)

Table D.4 – Test pulse 2b (12 V and 24 V system)

Test pulse 2b	V_s	t_r	t_d
No load and 0,5 Ω load	+ 10 V ± 1 V (12 V system) + 20 V ± 2 V (24 V system)	1 ms ± 0,5 ms	2 s ± 0,4 s

D.3.3 Test pulse 3

D.3.3.1 Test pulse 3a

Table D.5 – Test pulse 3a (12 V and 24 V system)

Test pulse 3a	V_s	t_r	t_d
No load	- 200 V ± 20 V	5 ns ± 1,5 ns	150 ns ± 45ns
50 Ω load	- 100 V ± 20 V	5 ns ± 1,5 ns	150 ns ± 45ns

D.3.3.2 Test pulse 3b

Table D.6 – Test pulse 3b (12 V and 24 V system)

Test pulse 3b	V_s	t_r	t_d
No load	+ 200 V ± 20 V	5 ns ± 1,5 ns	150 ns ± 45 ns
50 Ω load	+ 100 V ± 20 V	5 ns ± 1,5 ns	150 ns ± 45 ns

For verification of test pulses 3a/3b coaxial measuring devices shall be used. The spectrum of the pulses covers the frequency range up to 200 MHz. Within this range it is difficult to use high impedance voltage probes. The attached ground cable of the probe may cause significant ringing and may result in false measurements. Coaxial measuring devices therefore are strictly recommended.

D.3.4 Test pulse 4 (12 V and 24 V system)

No pulse verification is available

D.3.5 Test pulse 5

D.3.5.1 Test pulse 5a (12 V system)

Table D.7 – Test pulse 5a (12 V system)

Test pulse 5a	V_s	t_r	t_d
No load	+ 100 V ± 10 V	$\left(10\ {}^{0}_{-0,5}\right)$ ms	400 ms ± 80 ms
2 Ω load	+ 50 V ± 10 V	-	200 ms ± 40 ms

The pulse is calibrated at a test level of 100 V, a pulse width of 400 ms and a source impedance of R_i = 2 Ω into a 2 Ω terminating resistor. A terminating resistor of 2 Ω is regarded an optimum (no influence of losses due to cables and connectors).

D.3.5.2 Test pulse 5a (24 V system)

Table D.8 – Test pulse 5a (24 V system)

Test pulse 5a	V_s	t_r	t_d
No load	+ 200 V ± 20 V	$\left(10\ {}^{0}_{-0,5}\right)$ ms	350 ms ± 70 ms
2 Ω load	+ 100 V ± 20 V	-	175 ms ± 35 ms

Annex B: Mode Tuning Chamber Calibration (based on Draft 61000–4–21 IEC 2000)

B.1 Chamber Calibration and Loading Validation.

The empty chamber calibration shall be performed prior to the use of the chamber for testing using the procedures of this Appendix. Prior to each DUT test, a loading validation shall be performed according to the procedures of section B.2.

All calibrations are antenna specific. Changing antennas prior to a test shall require a new calibration. One loading validation (outlined in section B.2) is sufficient at the start of a test with multiple samples. Multiple loading validations are not required in between tests if the DUT being tested has not been significantly modified to affect its size and shape (i.e. circuit board alterations).

B.1.1 Field Uniformity Validation.

i Remove all non-essential equipment from the test chamber including DUTs, simulators, cameras, etc.

ii Place the transmitting antenna as indicated in the notes of Figure 7 directing it into a corner. The transmitting antenna shall not be moved during the field uniformity validation. The transmit antenna shall be linearly polarized and rated for the frequencies being tested. The transmit antenna shall remain in a fixed location for all calibrations and testing.

iii Place the receive antenna within the working volume of the chamber defined in the notes of Figure B.1. The receive antenna, probe, or chamber working volume shall not be in the direct path of the transmit antenna. The receive antenna shall be linearly polarized and rated for the frequencies being tested. The receive antenna shall also be cross polarized with respect to the transmit antenna.

iv Place an electric field probe (capable of reading three orthogonal axes) on the perimeter of the chamber working volume as shown in Figure B.1.

v At the lowest test frequency (fs = 400 MHz), inject an appropriate amount of RF power, into the transmit antenna. RF power shall be applied for an adequate dwell time to ensure that the amplitude measuring device and the electric field probes have time to respond properly. Harmonics of the RF input to the chamber must be at least 15 dB below the carrier frequency.

vi Step the tuner through 360° in discrete steps (mode-tuning) so that the amplitude measuring device connected to the receive antenna (e.g., spectrum analyzer, power meter, etc.) and electric field probes captures the minimum number of samples required as indicated in Table B.1.

Note: An appropriate amount of input power is dependent on the size and material of the test chamber as well as the noise floor of the electric field probe and amplitude measuring equipment.

vii Record the received power, the field strength for each axis of the electric field probe, and the input power for each step of the mode tuner. From these values compute the maximum received power, average received power (PMaxRec ,PAveRec), the maximum field strength for each axis of the electric field probe (EMax x, EMax y, EMax z), and the average input power (PInput) over one tuner rotation. All calculated values shall be in linear units (i.e. Watt, not dBm and V/m, not dBV/m). Ensure that the power measurement instruments have an equipment noise floor at least 20 dB below the maximum received power (PMaxRec) for proper average data collection.

Note: PInput is the forward power averaged over one tuner rotation. The number of samples used to determine PInput should be at least the same number of samples used for chamber calibration. All power measurements are relative to the antenna terminals (both forward and receive).

viii Repeat steps v. through vii. in log spaced frequency steps as indicated in Table B.1 until the frequency is at least 4000 MHz (10 fs).

ix Repeat steps v. through vii. for each of the eight probe locations shown in Figure B.1 and for eight antenna locations until 4000 MHz (10 fs). If the receive antenna will be in a specific position during routine testing, the antenna shall be in one of these positions during the eight runs.

Note: The order of steps vi. and viii. may be interchanged, i.e. step through all the frequencies at each step of the tuner.

x Above 4000 MHz (10·fs), only three antenna locations and electric field probe positions must be evaluated. Repeat steps v. through vii. for the remainder of the calibration frequencies as indicated in Table B.1. One of the probe locations shall be the center of the working volume and one of the antenna positions shall be the typical receive antenna position as described in step ix.

Note: The receive antenna shall be moved to a new location within the working volume of the chamber for each change in probe location. The receive antenna shall be oriented in a different direction for each position (a change in angle of 20° or greater is recommended). The electric field probes do not have to be oriented along the chamber axis during calibration as long as the electric field probe axes remain consistent with each probe position. A proper separation distance shall be maintained between the antenna and probe at each probe location. It is recommended that each probe location be at least 1 m (minimum distance 0.25 m) from any previous location.

xi Normalize each of the maximum electric field probe measurements (each of the 24 rectangular components below 10 fs, and 9 rectangular components above 10 fs) to the square-root of the average input power using the data from step vii.:

$$\ddot{E}_x = \frac{E_{Max_x}}{\sqrt{P_{Input}}}$$
$$\ddot{E}_y = \frac{E_{Max_y}}{\sqrt{P_{Input}}}$$
$$\ddot{E}_z = \frac{E_{Max_z}}{\sqrt{P_{Input}}}$$

where

$E_{Max_{x,y,z}}$ = maximum measurement from each probe axis (24 or 9 measurements)

$\ddot{E}_{x,y,z}$ = normalized maximum measurement from each probe axis

Pinput = average input power to transmit antenna during the tuner rotation at which EMax x,y,z was recorded

xii For each calibration frequency below 10 fs (4000 MHz), calculate the average of the normalized maximum of each probe axis of the electric field probe measurements:

$$\left\langle \ddot{E}_x \right\rangle = \left(\sum \ddot{E}_x \right) / 8$$
$$\left\langle \ddot{E}_y \right\rangle = \left(\sum \ddot{E}_y \right) / 8$$
$$\left\langle \ddot{E}_z \right\rangle = \left(\sum \ddot{E}_z \right) / 8$$

xiii For each calibration frequency below 10 fs (4000 MHz), calculate the average of the normalized maximum of all the electric field probe measurements:

$$\left\langle \ddot{E} \right\rangle_{24} = \sum \left(\ddot{E}_{ix} + \ddot{E}_{iy} + \ddot{E}_{iz} \right) / 24$$

i = 1,2, ... 8 (number of probe locations)
Note: < > indicates arithmetic mean, i.e.,

$$\left\langle \ddot{E} \right\rangle_{24} = \sum \left(\ddot{E}_{ix} + \ddot{E}_{iy} + \ddot{E}_{iz} \right) / 24$$

represents the sum of the 24 rectangular electric field normalized maximums divided by the number of measurements.

xiv Repeat step xii. for each frequency above 10 fs (4000 MHz), replacing 8 with 3.

xv Repeat step xiii. for each frequency above 10 fs (4000 MHz), replacing 24 with 9.

xvi For each frequency below 10 fs, verify that the chamber meets the field uniformity requirements by the following procedure:

a Field uniformity is indicated by the standard deviation from the mean value of the maximum electric field values obtained at each of the probe location during one complete rotation of the tuner. This standard deviation is calculated from data for each probe axis independently and the total data collected.
The standard deviation is the following:

$$\sigma = \alpha * \sqrt{\frac{\sum\left(\vec{E}_i - \left\langle\vec{E}\right\rangle\right)^2}{n-1}}$$

where
i = 1,2, ... 8 (number of probe locations)
n = number of measurements
$\vec{E}_i$ = maximum normalized electric field probe measurement
$\left\langle\vec{E}\right\rangle$ = arithmetic mean of the normalized electric field measurements
α= 1.06 for n $\lesssim$ 20 and 1 for n > 20
σ = standard deviation for a given axis (x, y, or z)

Example for the x-axis

$$\sigma_x = 1.06 * \sqrt{\frac{\sum\left(\vec{E}_{ix} - \left\langle\vec{E}_x\right\rangle\right)^2}{8-1}}$$

where
i = 1,2, ... 8
$\vec{E}_{ix}$ = maximum normalized electric field probe measurement of x axis
$\left\langle\vec{E}_x\right\rangle$ = arithmetic mean of normalized axes from all eight measurement locations
Example for all axes:

$$\sigma_{24} = 1 * \sqrt{\frac{\sum\left(\vec{E}_{ix,y,z} - \left\langle\vec{E}\right\rangle_{24}\right)^2}{24-1}}$$

where i = 1,2, ... 8
$\vec{E}_{ix,y,z}$ = maximum normalized electric field probe measurements of all axes (x, y, and z)
$\left\langle\vec{E}\right\rangle_{24}$ = arithmetic mean of normalized Emax x,y,z axes from all 24 measurements
σ_{24} = standard deviation of all axes (x, y, and z)
The standard deviation is expressed in terms of dB relative to the mean:

$$\sigma(dB) = 20 * log \frac{\sigma + \left\langle\vec{E}_{x,y,z}\right\rangle}{\left\langle\vec{E}_{x,y,z}\right\rangle}$$

b The chamber meets the field uniformity requirements if the standard deviation from the individual axes (x, y, and z), and the total data set (all axes) are less than 3 dB (a maximum of three frequencies per octave may exceed the allowed standard deviation by no greater than 1dB).

B.1.2 Receive antenna calibration.
The receive antenna calibration factor (ACF) for an empty chamber is established to provide a comparison with a loaded chamber. The ACF for each frequency is:

$$ACF = \left\langle \frac{P_{AveRec}}{P_{Input}} \right\rangle_{8\ for \le 10\ f_S,\ 3\ for \ge 10\ f_S}$$

where
PInput is the average input power from B.1.1.vii. for the location at which the average received power PAveRec from B.1.1.vii. was measured

B.1.3 Chamber Insertion Loss.
The chamber insertion loss (IL) for the chamber is given by the following:

$$IL = \left\langle \frac{P_{MaxRec}}{P_{Input}} \right\rangle_{8\ for \le 10\ f_S,\ 3\ for \ge 10\ f_S}$$

where
P_{Input} is the average input power from B.1.1.vii. for the location at which the maximum received power P_{MaxRec} from B.1.1.vii. was measured.

B.1.4 Maximum Chamber Loading Verification.
The following procedure is used to determine if the chamber is affected by a DUT which loads (absorbs a significant amount of energy) the chamber. This procedure should be performed once in the life of the chamber or whenever the chamber has undergone major structural modifications. Prior to each test, a chamber calibration shall be performed according to section B.2.

i Install a significant amount of absorbing material (e.g., foam absorber) in the chamber to load the chamber to the amount expected during normal testing (a factor of sixteen or 12dB is typical).

ii Repeat the calibration procedure from section B.1.1. using eight or three locations of the field probes according to the frequency (eight < 10 fs, three > 10 fs). The electric field probes and receive antenna should be a minimum of 0.25 m away from any absorbing material. Determine the chamber loading by comparing the ACF of an unloaded chamber with the ACF of a loading chamber as follows:

$$Loading = \frac{ACF_{Empty\ Chamber}}{ACF_{Loaded\ Chamber}}$$

iii Repeat the field uniformity calculations as described in section B.1.1.xvi.

iv If either the field uniformity of the individual rectangular components or the field uniformity for all axes (x, y, and z) is greater than the allowed standard deviation indicated in section B.1.1.iv, then the chamber has been loaded to the point where field uniformity is unacceptable. Reduce the amount of loading and repeat the loading effects evaluation.

B.2 Calibration and DUT Loading Check.
The following procedure shall be performed prior to each test of the DUT. The DUT and any necessary supporting equipment must be installed into the chamber. If the chamber was initially tested under maximum loading conditions, the loading check prior to each test is optional.

i Place the receive antenna within the working volume (see B.1.1.x.) at least 0.25 m from the DUT and supporting equipment.

ii At the lowest test frequency (fs = 400 MHz), inject an appropriate amount of RF power, into the transmit antenna. Harmonics of the RF input to the chamber must be at least 15 dB below the carrier frequency.

iii Operate the chamber and the tuner for the desired number of steps as indicated in Table B.1 (alternatively, mode stirring is allowed with a maximum stir speed of 16.5 seconds per tuner revolution). RF power shall be applied for an appropriate amount of dwell time to ensure that the amplitude measuring device has time to respond properly.

iv Calculate the maximum received power, average received power (PMaxRec, PAveRec), and the average input power (PInput) over one tuner rotation. All calculated values shall be in linear units (i.e. W, not dBm; V/m, not dBV/m). Ensure that the power measurement instruments have an equipment noise floor at least 20 dB below the maximum received power (PMaxRec) for proper average data collection.

v Repeat step iv. for each frequency defined in Section 3.4.

vi The chamber calibration factor (CCF) for each frequency is as follows:

$$CCF = \left\langle \frac{P_{AveRec}}{P_{Input}} \right\rangle_n$$

where CCF = the normalized average received power over one tuner rotation with the DUT and support equipment in the chamber
PAveRec= average received power over one tuner rotation from step vii.
PInput= forward power averaged over one tuner rotation from step vii.
n = number of antenna locations the CCF is evaluated over. Only one is required, however multiple antenna positions may be used and the CCF averaged over the number of locations.

vii Determine the chamber loading factor (CLF) for each frequency as follows:

$$CLF = \frac{CCF}{ACF}$$

where
CCF = the ratio of the average received power to the input power obtained from step vi.
ACF = the ratio of the average received power to input power obtained in the antenna calibration of section B.1.2. Use linear interpolation to obtain the ACF.

If the magnitude of the chamber loading factor is larger than that measured in section B.1.4. for more than 10 % of the frequencies, the chamber is loaded and the field uniformity is affected. If this happens, the field uniformity measurements of section B.1.1.must be repeated with the DUT in the test chamber.

Note: If the PAveRec measured in B.2.iv is within (i.e., not greater than or less than) the values recorded for all eight locations in section B.1.1.vii, the CLF calculation is not necessary and the value of CLF is one (1).

B.3 Q and Time Constant Calibration.

These measurements are conducted to ensure that the chamber can support the pulse waveforms outlined in Section 3.4.3

i Calculate the quality factor, Q, of the chamber using the CCF of section B.2.vi. for each frequency:

$$Q = \left(\frac{16\pi^2 V}{\eta_{Tx}\eta_{Rx}\lambda^3} \right)(CCF)$$

where
η_{Tx}, η_{Rx} = the antenna efficiency factors for the transmit and receive antenna which can be assumed to be 0.75 for a log periodic antenna and 0.9 for a horn antenna.
V = the chamber volume (m^3)

λ = wavelength at the specific frequency
CCF = chamber calibration factor

Note: If the CLF was assumed to be one (1) from step B.2.vii, the ACF from section B.1.2 shall be used in place of the CCF when computing chamber Q.

ii Determine the chamber time constant, t, for every frequency using the following:

$$\tau = \frac{Q}{2\pi f}$$

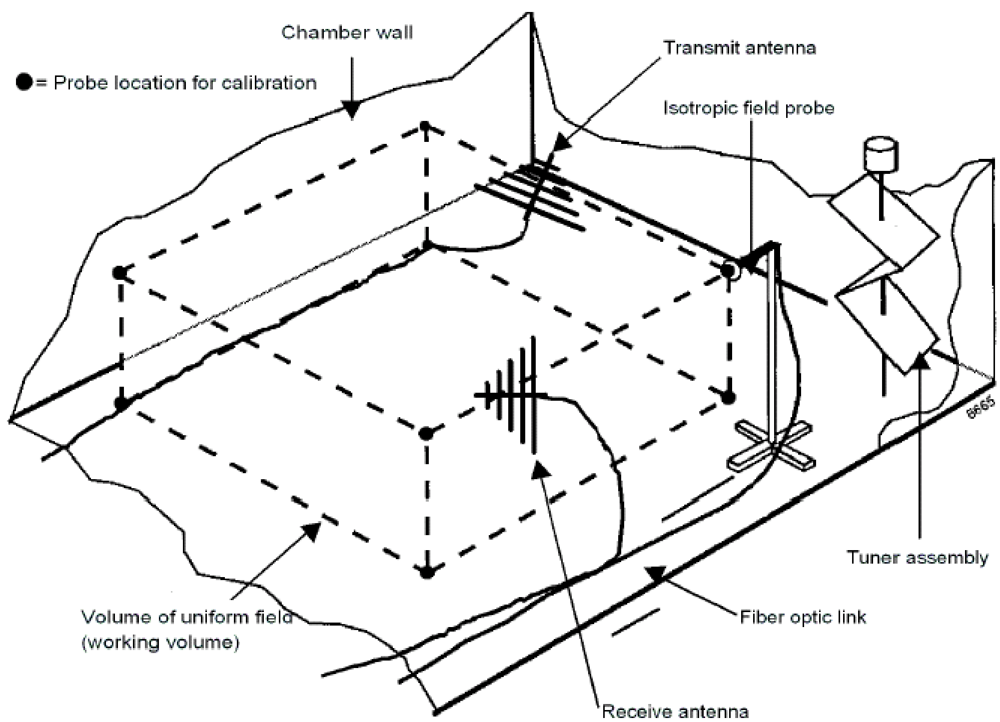
where
Q = the value calculated in step i, above
f = the test frequency (Hz)

iii If τ > (0.4 * the pulse width) given in Section 3.4.3 for more than 10 % of the test frequencies, absorber material must be added and the Q measurement must be repeated. The CLF calculations must be repeated if absorber material is to be added.

Table B.1: Independent samples and frequencies

Frequency range (MHz)	Minimum number of samples (i.e. independent tuner positions or intervals) for calibration and test	Number of frequencies (logarithmically spaced) required for calibration
400 ... 1000	12	20
1000 ... 4000	6	15
> 4000	6	20 / decade

Figure B.1: Reverberation Test Configuration (Mode Tuning)



Note: Calibration shall consist of eight probe locations below 10 fs (4000 MHz) and three locations above 10 fs (4000 MHz).

Note: The locations selected shall enclose the "working volume" as shown above. The working volume should be located at least 1 meter from the chamber walls, mode tuning device, and transmitting antenna.

Note: The receive antenna must be located in the working volume for calibration purposes as described in B.1.1.iii. The transmit antenna shall be pointed into a corner at least 0.25 m away from the chamber surface. The transmit antenna shall remain in a fixed location for all calibrations and testing.

Note: The working volume may be sized to suit the size of the DUT's to be tested.

Note: The minimum separation distance may be reduced less than 1 m provided that the separation distance is always at least 0.25 m.

Annex C: Typical Measurement problems.

- Power for the DUT should be supplied from a source free of electromagnetic emissions (e.g. batteries, linearly-regulated power supply). The use of switching power supplies is not recommended. If a power supply is used to simulate the battery, the low output impedance of the battery must be simulated. Using an actual battery or power supply capable of supplying at least twice the rated inrush current of the DUT is recommended.

- Experience has shown that double shielded coaxial cable may be necessary to connect measurement equipment. Additionally, RF common mode chokes, such as ferrite cores, may be required on the cabling to reduce measurement errors.

- Placing the measurement instrumentation in a shielded or anechoic room may add to the background noise level. Extreme caution must be taken as to placement of equipment and personnel if repeatable results are to be obtained.

- Since resonant frequencies may change from the bench setup to the vehicle, frequencies of noncompliance found during component testing may not necessarily be the same as the frequencies of noncompliance found during full-vehicle testing.

- Through experience it has been noticed that continuously generating the maximum rated output of an amplifier into a severe mismatch tends to limit its operating life. Therefore it may be beneficial to purchase a higher power amplifier than needed for each test.

- The interconnecting harness between a simulator and the DUT should be long enough to ensure that the simulator is not adversely affected by the magnetic field during magnetic field testing.

Annex D: Emissions Test Report Sample

Non-Spark Device
GMW3097 AN & ALSE Test Results

Part Description: *Unknown Device*
Mode: *Undefined Mode*
Notes: *None*

Test Number: *MC-????*
Date Tested: *Anytime*
File Name: *Anyname*

Part Category: ***A***

Supplier Name: *Anyone Parts Inc.*
Engineer Name: *Joe Somebody*
Supplier Phone: *(111) 555-5555*

Lab Name: *Anylab LLC*
Operator Name: *Someone*
Operator Phone: *(111) 666-6666*

Band	Region	RF Service Name	Start Freq. (MHz)	Stop Freq. (MHz)	Maximum Emission	Non-Spark Limit	Detector
Artificial Network (AN) Conducted Emission (CE)					**dBuV**	**dBuV**	
EU1	Europe	Long Wave (Note 1)	0.15	0.28	29	73	PK
G1	Global	Medium Wave / AM	0.53	1.71	35	42	PK
Aborber Lined Chamber (ALSE) Radiated Emissions (RE)					**dBuV/m**	**dBuV/m**	
EU1	Europe	Long Wave (Note 1)	0.15	0.28	29	41	PK
M1	Global	Medium Wave / AM	0.53	1.71	**35**	30	PK
NA1	America	DOT I	45.2	47.8	8	12	PK
G2	Global	4 Meter	62.5	88.1	**22**	12	PK
JA1	Japan	FM I	75.2	90.9	10	12	PK
G3	Global	FM II (except Japan)	86.6	109.1	11	12	PK
G4	Global	2 Meter	140.6	175.8	**17**	12	PK
EU2	Europe	Digital Audio Broadcast (DAB)	174.1	240	**35**	12	PK
G5	Global	RFA/TPMS I	314	316	8	20	PK
G6	Global	RFA/TPMS II	433	435	12	25	PK
G8	Global	Global Positioning System (GPS)	1567	1583	7	50-10-50	AVG

Note 1: Optional, applies to products intended for Fiat vehicles

Emissions Exceed Limit for Band
Emisions Meet Limit for Band