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

Verification Part

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.

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

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

1.1 Scope. This document applies to the Electromagnetic Compatibility (EMC) of electrical / electronic components and subsystems for passenger vehicles, light duty trucks and medium duty trucks. It is accepted by all parts of General Motors (GM) and, therefore, applicable to all GM automotive products worldwide.

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

GMW3091, GMW3094, GMW3097, GMW3100, GMW3103 and GMW3106

Note: All six documents of equal revision are carrying the same release date.

Note: During development of this document it was first called GMW 12559 and then GMW 12002 V.

1.2 Mission / Theme. This document specifies test procedures for verification of compliance to EMC requirements defined in GMW3097. It refers to International EMC Standards whenever possible but also describes GM internal test procedures if necessary.

2 References

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

2.1 Normative.

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

2.2 GM.

GMW3091
GMW3094
GMW3097
GMW3103
GMW3106

3 Test of Requirements

3.1 Test Equipment and Test Samples.

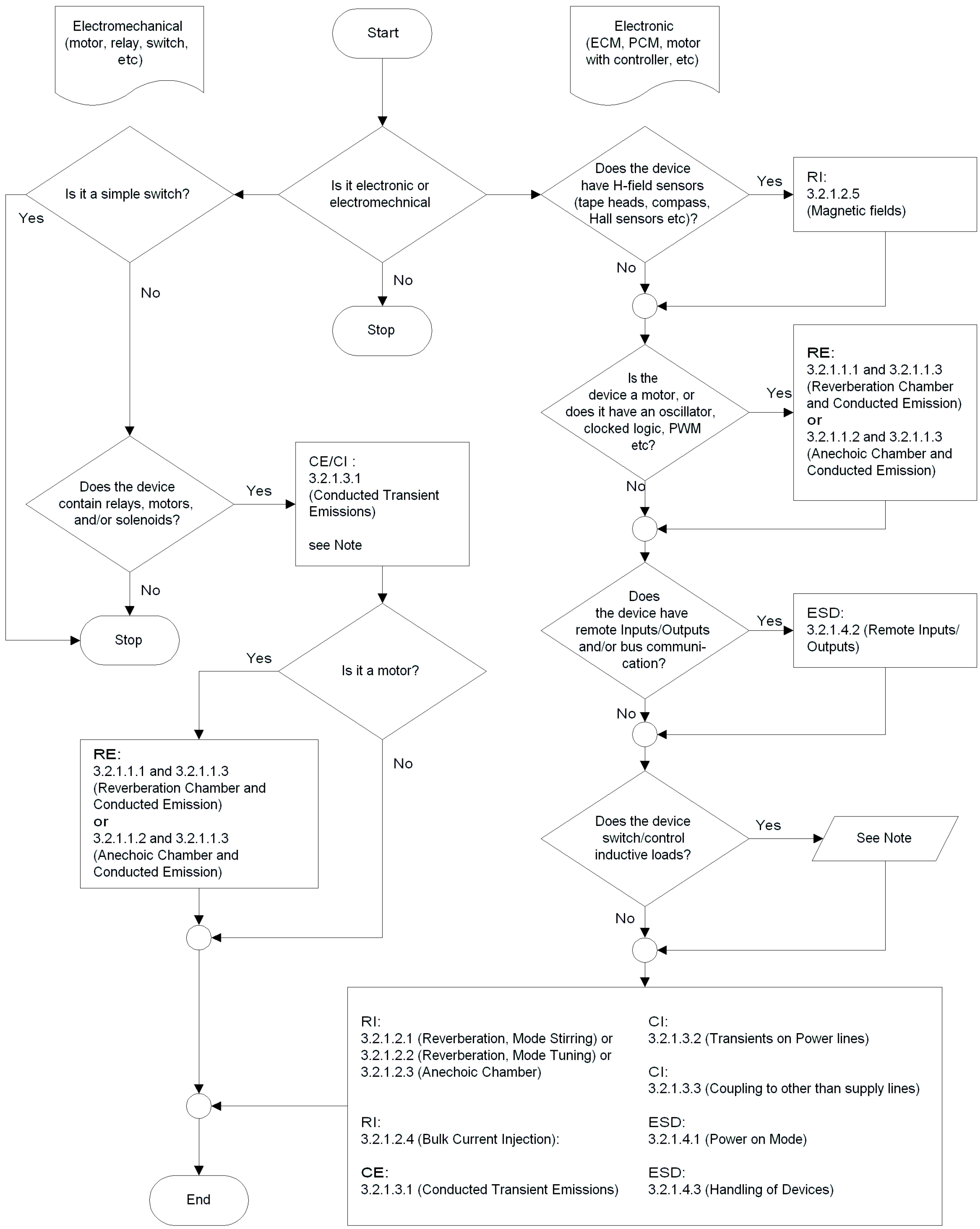
3.1.1 Test Equipment. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Test Samples. Minimum 2 samples, see GMW3103.

3.2 Test of Product Characteristic.

3.2.1 Test of Performance Requirements. The flowchart in Figure 1 is supplied as a guide only for the selection of the minimum tests applicable to electrical / electronic components and subsystems. The result of following this flowchart may not be all inclusive. The final list of applicable tests is to be determined by the Release Engineer.

Figure 1: Flowchart to aid in the Determination of applicable Component and Subsystem Tests.



Note: While not a preferred methodology, some system designs incorporate suppression for inductive loads into a controlling electrical / electronic device, rather than internal to the actual load. For these cases, the inductive load would be exempt from paragraph 3.2.1.3.1.

3.2.1.1 Radiated Emissions, Component Tests.

Note: The Anechoic Chamber Test and the Reverberation Chamber Test are currently considered to be equivalent. This implies that either test method according to Paragraph 3.2.1.1.1, Reverberation Chamber Test, or test method according to Paragraph 3.2.1.1.2, Anechoic Chamber Test, can be used.

3.2.1.1.1 Reverberation Chamber Test.

3.2.1.1.1.1 Purpose. The test methods in this paragraph specify procedures for measuring radiated emissions of electrical / electronic components and subsystems to protect receivers against disturbances from these devices using the reverberation test method.

For this test method correlation must be established with GMNA Milford Proving Ground facility.

3.2.1.1.1.2 Test 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: Depending on the frequency range the following antennas shall be used:

- Active Monopole (Emco 3301B or equivalent).

  Frequencies covered: 150 kHz...20 MHz.

  Reference point: Intersection of rod and ground plane.

- Biconical.

  Frequencies covered: (20...200) MHz.

  Reference point: Midpoint of elements.

- Log-Periodic.

  Frequencies covered: (200...1000) MHz.

  Reference point: Front boom tip.

- Horn.

  Frequencies covered: (1000...2500) MHz.

  Reference point: Front aperture.

Simulator: A simulator with a 3 m 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.

Note: 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:

length X width X height

3.61 m X 4.83 m X 3.05 m

Tuner or Stirrer: Refer to SAE J1113/27 for mode stirrer specifications.

Note: Electromagnetic emissions of any support equipment (simulator / load box) necessary to run the DUT shall be at least 6 dB below the radiated emissions requirements so that their noise can be considered part of the measurement system noise.

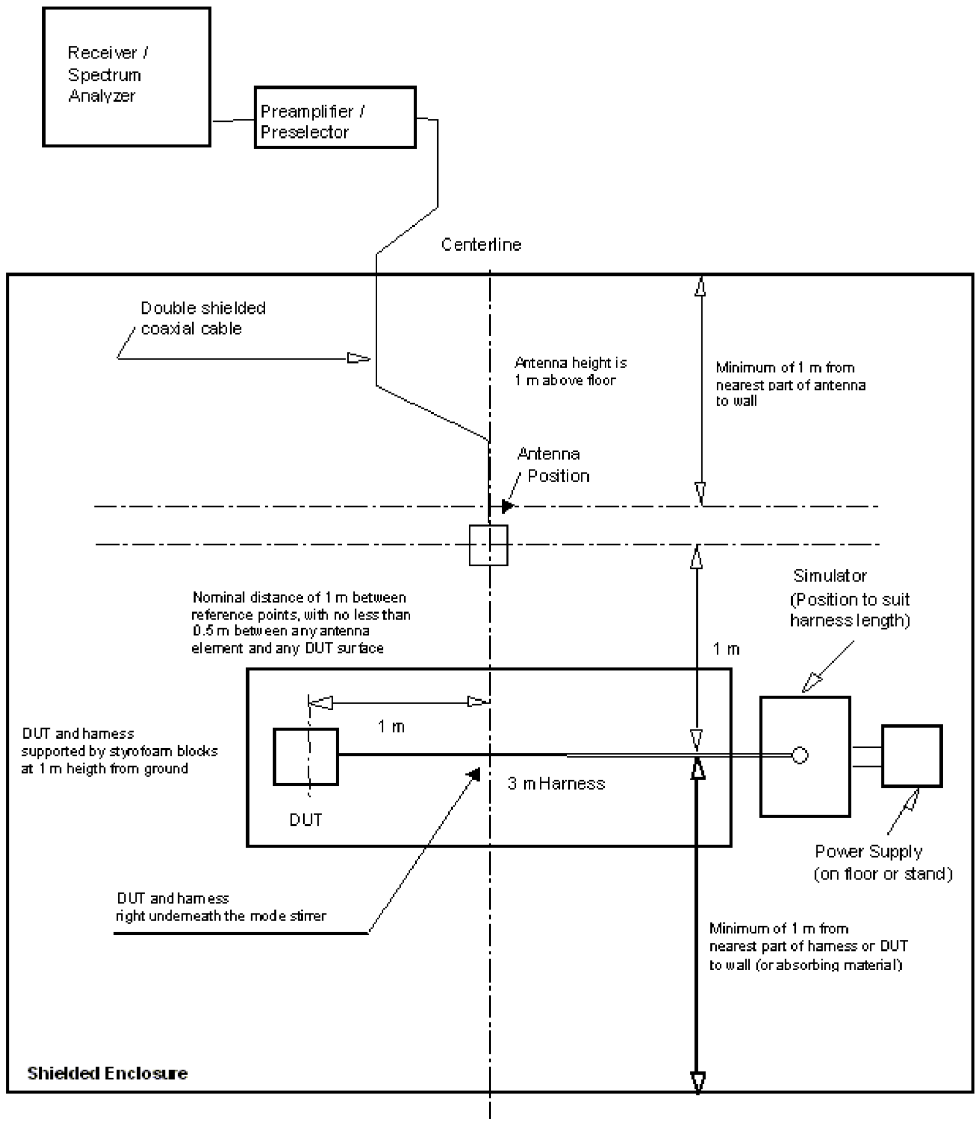
3.2.1.1.1.3 Test Procedure. Noise is divided into three different categories:

- Spark generated noise: Noise generated by sparks, such as ignition systems, brush type motors etc.
- Non-spark generated noise: Noise generated by electronic sources, such as microprocessors, clocks, PWM etc.
- Switch pop noise: Noise generated due to switching of a contact, such as brake light switch, turn signal relays, etc.

Note: For systems which generate more than one category of noise, each category has to be tested separately.

Use the test setup according to Figure 2.

Figure 2: Test Setup for Radiated Emissions, Reverberation Chamber Test.



The applicable frequency range of 150 kHz...2.5 GHz is divided into 15 bands as shown in Table 1. A complete dataset of frequency -vs- field strength shall be reported for each band.

Table 1: Frequency Bands and Corresponding Resolution Bandwidth (RBW) Selection (Values for Test Receivers in parenthesis).

Frequency Band in MHz	RBW for non-spark generated noise in kHz	RBW for spark generated noise in kHz	Comments
0.15...3	10	10	
3...20	10	10	
20...100	10	10 / 100 (120)	When measuring spark generated emissions within the frequency range of (20...200) MHz, the RBW's of 100 (120) kHz shall be used only for the sub-band of (74.5...110) MHz; all other frequencies within this (20...200) MHz band shall be measured with the 10 kHz RBW for spark generated emissions
100...200	10	10 / 100 (120)	
200...400	10	10	
400...800	10	10	
800...1000	10	10	
1447...1503	10	10	
1543...1561	10	10	
1567...1583	10	10	
1803...1882	10	10	
1928...1992	10	10	
2108...2172	10	10	
2308...2362	10	10	
2398...2499	10	10	

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.

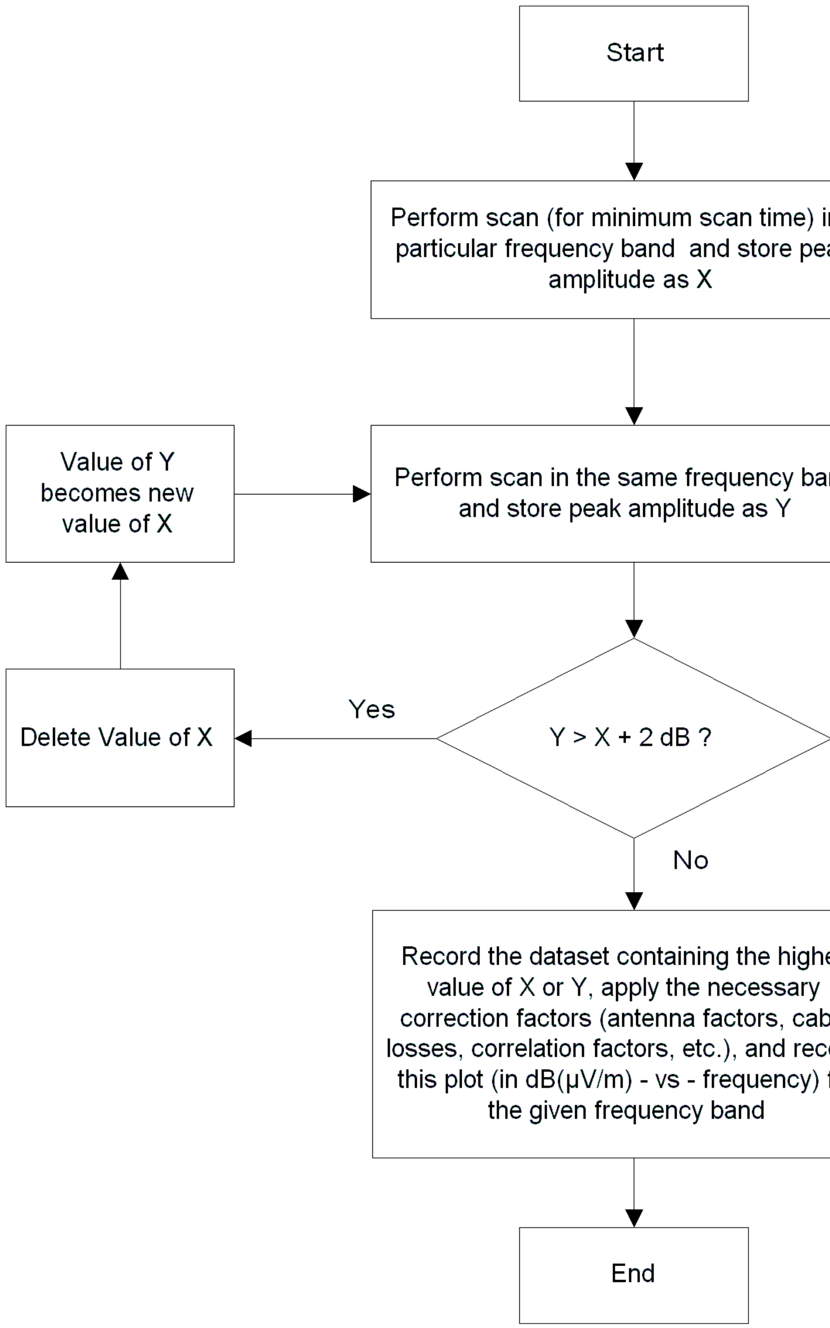
Mode stirring: Above 20 MHz mode stirring shall be used. Mode stirring is a reverberation technique that uses a continuously rotating stirrer during testing.

Below 20 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 s per revolution.

For each frequency band, follow the algorithm of Figure 3:

Figure 3: Flowchart to Determine Emissions in a Frequency Band.



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

- Plots for each frequency band listed in Table 1 or a single summary plot. Data shall be plotted as dB(µV/m) versus frequency.
- The appropriate limit line on each plot.

3.2.1.1.2 Anechoic Chamber Test.

3.2.1.1.2.1 Purpose. The test methods in this paragraph specify procedures for measuring radiated emissions of electrical / electronic components and subsystems to protect receivers against disturbances from these devices using the anechoic chamber test method.

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

3.2.1.1.2.3 Test Procedure. Noise is divided into three different categories:

- Spark generated noise: Noise generated by sparks, such as ignition systems, brush type motors etc.
- Non-spark generated noise: Noise generated by electronic sources, such as microprocessors, clocks, PWM etc.
- Switch pop noise: Noise generated due to switching of a contact, such as brake light switch, turn signal relays, etc.

Note: For systems which generate more than one category of noise, each category has to be tested separately.

Use test method IEC CISPR 25 with the following specifications:

- At frequencies above 30 MHz, testing with horizontal and vertical antenna polarization and with 3 orthogonal DUT orientations is required.
- The RBW shall be 10 kHz from (0.15...2500) MHz.
- In the frequency range (0.15...1000) MHz the antenna shall be oriented as described in IEC CISPR 25.
- For the frequency range (1...2.5) GHz the antenna shall be moved 0.75 m parallel to the front edge of the ground plane towards the DUT in order to point at the DUT instead of the center of the wiring harness.

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

- The frequency spectrum measured with all DUT and antenna orientations shall be included in one plot. Data shall be reported as dB(µV/m).
- The appropriate limit line.

3.2.1.1.3 Conducted Emissions, Test with the Artificial Network.

3.2.1.1.3.1 Purpose. The test methods in this paragraph specify procedures for measuring line conducted emissions of electrical/electronic components and subsystems to protect receivers against disturbances from these devices.

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

3.2.1.1.3.3 Test Procedure. Use test method IEC CISPR 25 with the following specifications:

- Use Pk+-detector

Note: 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 (1500 ±75) mm can be chosen.

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

- The frequency spectrum measured. Data shall be reported as dB(µV).
- The appropriate limit line.

3.2.1.2 Radiated Immunity, Component Tests.

Note: The Anechoic Chamber Test and the Reverberation Chamber Test are currently considered to be equivalent. This implies that either test method according to Paragraph 3.2.1.2.1, Reverberation Chamber Test, Mode Stirring, or test method according to Paragraph 3.2.1.2.2, Reverberation Chamber Test, Mode Tuning, or test method according to Paragraph 3.2.1.2.3, Anechoic Chamber Test, can be used.

Use the test frequencies determined by the following equation for the frequency ranges in Table 2 for the following tests:

- 3.2.1.2.1 Reverberation Chamber Test, Mode Stirring.
- 3.2.1.2.2 Reverberation Chamber Test, Mode Tuning.
- 3.2.1.2.3 Anechoic Chamber Test.
- 3.2.1.2.4 Bulk Current Injection.

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

where

f_0 base frequency

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

n number of steps per octave

Table 2: Test frequency calculation

Frequency range	f_0	n	lowest test frequency in range	Corresponding Q
1 MHz...< 30 MHz	1 MHz	7	1 MHz	10
30 MHz...< 400 MHz	30 MHz	25	30 MHz	36
400 MHz...< 1 GHz	400 MHz	25	400 MHz	36
1 GHz...10 GHz	1000 MHz	50	1 GHz	72

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

Example: For the frequency range 5.4 GHz...5.7 GHz, the test frequencies are (rounded to 4 significant digits):

k	f_{test}
122	5.426 GHz
123	5.502 GHz
124	5.579 GHz
125	5.657 GHz

When deviations occur, care must be given in identifying the deviation profile accurately.

3.2.1.2.1 Reverberation Chamber Test, Mode Stirring.

3.2.1.2.1.1 Purpose. This test method specifies a procedure for testing the immunity of electrical / electronic components and subsystems to radiated electromagnetic fields. This test is applicable to the frequency range between 400 MHz and 10 GHz.

Note: This test method “mode stirring” is still accepted but will not be allowed when the next revision of this document is released.

3.2.1.2.1.2 Test Equipment. The test equipment shall comply with SAE J1113/27 from 400 MHz...10 GHz with the following specifications:

- The use of electric field probes is not required.

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.

3.2.1.2.1.3 Test Procedure. The test procedure shall comply with SAE J1113/27 from 400 MHz...10 GHz with the following specifications:

- Use test frequencies according to Table 2 and the equation.
- A (1500 ±75) mm harness shall be used unless otherwise specified in the test plan.
- The stirrer revolution rate shall be (16.5 ±1) s per revolution.
- The DUT shall be exposed to each field level and frequency for one stirrer revolution.
- The load box / simulator shall be located within the test chamber.
- Electrically monitored signals shall be measured using high impedance connections to avoid coupling to the chamber wall.

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

3.2.1.2.1.4 Test 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.
- The appropriate requirement shall be displayed on the immunity threshold plot of the DUT.

3.2.1.2.2 Reverberation Chamber Test, Mode Tuning.

3.2.1.2.2.1 Purpose. This test method specifies a procedure for testing the immunity of electrical / electronic components and subsystems to radiated electromagnetic fields. This test is applicable to the frequency range between 400 MHz and 10 GHz.

3.2.1.2.2.2 Test 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 as specified in GMW3097 Section 3.2.1.2.2.
- Transmit antenna: Linearly polarized antenna capable of satisfying frequency requirements. The transmit antenna shall avoid direct illumination of the test volume.
- Receive antenna: Linearly polarized antenna capable of satisfying frequency requirements. The receive antenna shall avoid direct illumination of the test volume.
- Power amplifiers: to amplify the RF signal and provide the necessary power to the transmit antenna to produce the field strengths specified in GMW3097 Section 3.2.1.2.2.
- Associated equipment to record the power levels necessary for the required field strength and to control the generation of that level for testing.
- 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.

3.2.1.2.2.3 Test Procedure.

- Use test frequencies according to Table 2 and the equation.
- The test setup is shown in Figure 7 of this document.
- Electric field probes shall not be used during the test.
- 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 Appendix B, section B.1.1 (Field Uniformity Validation).
- Prior to collecting data, the procedures of Appendix B, section B.2 (Calibration and DUT loading check) shall be performed.
- The transmit antenna shall be in the same location as used for calibration according to Appendix B.
- A (1500 ±75)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 load box/simulator shall be located within the test chamber.
- Electrically monitored signals shall be measured using high impedance connections to avoid coupling to the chamber wall.
- The chamber input power for the electric field levels given in GMW3097 Section 3.2.1.2.1.1 is determined via the equation:

$$Test\ Input\ Power = \left[\frac{E_{test}}{\left\langle \overleftrightarrow{E} \right\rangle_{24\ or\ 9} * \sqrt{CLF(f)}} \right]^2$$

where

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

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

$\left\langle \overleftrightarrow{E} \right\rangle_{24\ or\ 9}$ = normalized electric field from the empty chamber calibration from Appendix B, section B.1. It may be necessary to linearly interpolate (CLF and normalized electric field values) between the calibration frequency points.

3.2.1.2.2.4 Test 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.
- The appropriate requirement shall be displayed on the immunity threshold plot of the DUT.

3.2.1.2.3 Anechoic Chamber Test.

3.2.1.2.3.1 Purpose. This test method specifies a procedure for testing the immunity of electrical / electronic components and subsystems to radiated electromagnetic fields. This test is applicable to the frequency range between 400 MHz and 10 GHz.

3.2.1.2.3.2 Test Equipment. The test equipment shall comply with ISO 11452-1 and ISO 11452-2 from 400 MHz...10 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...10) GHz the field generating device (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.
- Horizontal and vertical polarization shall be used.
- For calibration and during the actual test of a DUT forward power shall be used as reference parameter.

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.

3.2.1.2.3.3 Test Procedure. The test procedure shall comply with ISO 11452-2 from 400 MHz...10 GHz with the following specifications:

- Use test frequencies according to Table 2 and the equation.
- The load box /simulator shall be located within the test chamber.
- Electrically monitored signals shall be measured using high impedance connections to avoid coupling to the chamber wall.

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

3.2.1.2.3.4 Test 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.

3.2.1.2.4 Bulk Current Injection.

3.2.1.2.4.1 Purpose. This test method specifies a procedure for testing the immunity of electrical / electronic components and subsystems to radiated electromagnetic fields. This test is applicable to the frequency range between 1 MHz and 400 MHz.

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

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

- Use test frequencies according to Table 2 and the equation.
- Use calibrated injection probe method (substitution method) according to ISO 11452-4 with the three fixed injection probe positions (150 mm, 450 mm and 750 mm).
- Use wiring harness length of (1500 ±75) mm
- In the frequency range 1 MHz...30 MHz all ground wires of the DUT wiring harness shall be routed outside of the injection probe (DBCI).
- In the frequency range 30 MHz...400 MHz all wires of the DUT wiring harness shall be routed inside of the injection probe (CBCI).
- For calibration and during the actual test of a DUT forward power shall be used as reference parameter.
- Use modulation as specified in GMW3097.
- The load box /simulator shall be located within the test chamber.
- Electrically monitored signals shall be measured using high impedance connections to avoid coupling to the chamber wall.
- The negative lead of the power supply for the DUT shall be tied to the ground plane with a low RF impedance connection.
- The injection probe shall be insulated from the ground plane.
- CW and AM dwell time shall be at least 2 s.

- 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, 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.

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

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

- Tabular data and plots from the three probe positions.
- Combined tabular data and plots to form a single worst case data set for each deviation title.

Note: 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.

3.2.1.2.5 Immunity to Power Line Magnetic Fields.

3.2.1.2.5.1 Purpose. This test method specifies a procedure for testing the immunity of electrical / electronic components and subsystems to power line magnetic fields.

3.2.1.2.5.2 Test Equipment. The test equipment shall comply with SAE J1113/22 with the following exceptions:

- Lower operating frequency of the equipment shall be at least $16\frac{2}{3}$ Hz.
- Upper operating frequency of the equipment shall be at least 180 Hz.
- Sine wave generator shall be used.

Table 3: Test Frequencies and Waveforms for the Magnetic Field Test.

Frequency in Hz	Signal Generator Voltage Output Waveform
$16\frac{2}{3}$	sine wave
50	sine wave
60	sine wave
150	sine wave
180	sine wave

3.2.1.2.5.3 Test 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 s.
- Use the test frequencies and waveforms according to Table 3.
- 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.

3.2.1.2.5.4 Test 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.

3.2.1.3 Conducted Transient Emissions and Immunity (CE/CI), Component Tests.

3.2.1.3.1 Conducted Transient Emissions.

3.2.1.3.1.1 Purpose. This test method specifies a procedure for testing the conducted emission of electrical transients of components and subsystems.

3.2.1.3.1.2 Test Equipment. The test equipment shall comply with ISO 7637-1 and ISO 7637-2.

3.2.1.3.1.3 Test Procedure. Use test methods according to the relevant sections of ISO 7637-2 with the following specifications:

- The test voltage shall be (13.5 +0.5/-1) V
- The test shall be performed according to ISO 7637-2, Figure 1b, but without the shunt resistor Rs.

Note: 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.

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

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

3.2.1.3.2 Conducted Transient Immunity, Transients on Power Lines.

3.2.1.3.2.1 Purpose. This test method specifies a procedure for testing the immunity of electrical / electronic devices to electrical transients on power lines.

3.2.1.3.2.2 Test Equipment. The test equipment shall comply with ISO 7637-1 and ISO 7637-2.

- 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 which correctly predict in-vehicle behavior. 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.

  Note: 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).

3.2.1.3.2.3 Test Procedure.

Note: If not otherwise stated, this test procedure applies to battery+ (B+) and switched battery lines (e.g. ignition, switched ignition, accessory ignition, run 1). 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 each I/O line separately. In addition, B+ and switched battery lines shall be tested simultaneously.

Note: The indicated time between test pulses (Period t_1) is a default value. Each DUT function 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 and the number of pulses applied should maximize the probability that a test pulse is applied during times of highest DUT susceptibility.

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

- The test voltage for all pulses with the exception of pulse 4 shall be (13.5 +0.5/-1) V
- For Pulse 4 the test voltage shall be 12 V

Perform the test using pulses 1, 2a, 2b, 3a, 3b, and 4 in accordance with ISO 7637-2.

Note: Pulse 1 and 2b are only applicable to switched battery lines.

Note: For Pulse 2a, battery shall remain connected for the duration of the pulse.

Note: The waveform amplitude for pulse 3a, 3b is determined from the average of the waveform peak voltages.

Note: Pulse 4 is only applicable to B+ and switched battery lines which are powered during cranking.

Additionally the following tests shall also be performed (test pulses 5 and 7a):

Test Pulse 5, Load dump:

Use the test setup according to the relevant sections of ISO 7637-2.

a Remove the suppression network and verify that the open circuit voltage waveform meets the specifications of Figure 4 and Table 4 (unsuppressed case, for verification purposes only).

b Connect the suppression network and verify that the open circuit voltage waveform meets the specifications of Figure 4 and Table 4 (suppressed case).

c Connect the 2 Ω load and verify that the suppressed loaded open circuit voltage waveform meets the specifications of Figure 4 and Table 5.

d Replace the 2 Ω load with the DUT and begin test.

Figure 4: Test Pulse 5: Load Dump Voltage waveform.

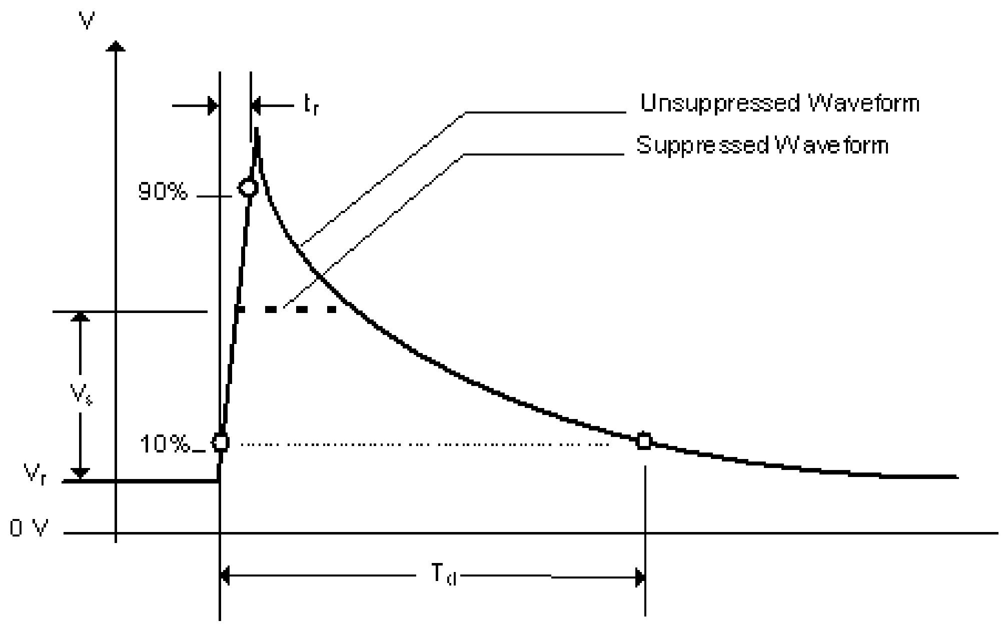


Table 4: Open Circuit Load Dump Pulse Parameters Specifications.

Parameter	Unsuppressed	Suppressed
$V_s + V_r$	+100 V ±10 %	(+34 +0/-1) V
T_d	400 ms ±30 %	400 ms ±30 %
t_r	≤ 10 ms	≤ 10 ms

Table 5: Two Ohm Loaded Load Dump Voltage Pulse Parameter Specifications.

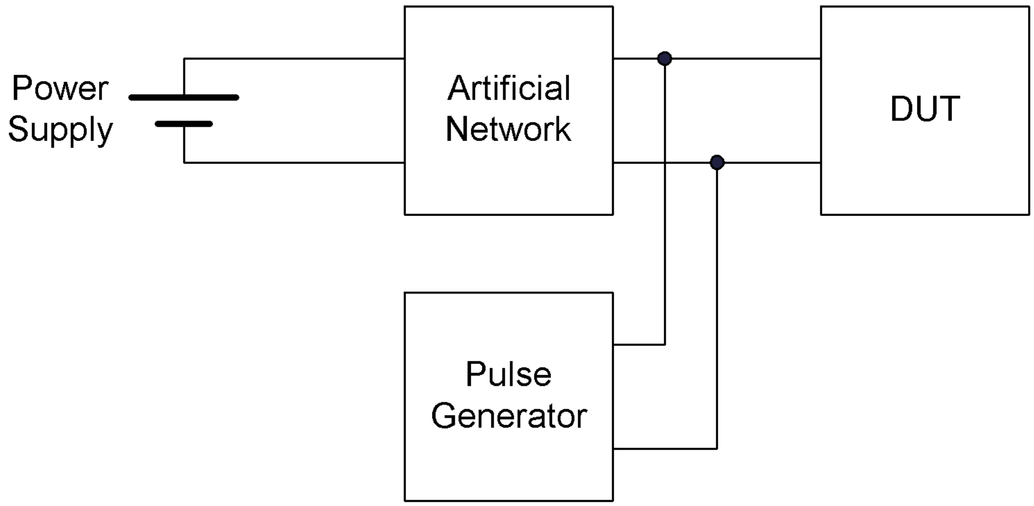
Parameter	Suppressed
$V_s + V_r$	(+34 +0/-1) V
T_d	≥ 100 ms
t_r	≤ 10 ms

Test pulse 7a (negative polarity), simulation of wiper motor switching transient:

Use the test setup in Figure 5 and apply the following pulses:

- ISO pulse 2a with negative polarity and a source resistance of 2 Ω ±10 %. The supply voltage is not switched off during application of the pulse.
- Use 5 µH Artificial Network.

Figure 5: Test Setup for Test Pulse 7a (Simulation of wiper motor switching transient).



Use Table 6 to determine the number of pulses or test time for pulses 1...7.

Table 6: Number of Pulses or Test Time for Pulses 1...7.

		Pulse period	
Test pulse	**Minimum number of pulses or test time**	**min**	**max**
1	500 pulses	0.5 s	5 s
2a	500 pulses	0.5 s	5 s
2b	10 pulses	0.5 s	5 s
3a	10 min	90 ms	110 ms
3b	10 min	90 ms	110 ms
4	1 pulse of each severity level	15 s	2 min
5	10 pulses	15 s	2 min
7a	500 pulses	0.5 s	5 s

3.2.1.3.2.4 Test 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 period (interval between pulses).
- Injection points (pin number, letter, or name.)
- Performance of the functions monitored during and following application of each transient.

3.2.1.3.3 Conducted Transient Immunity, Coupling to other than Supply Lines (I/O lines).

3.2.1.3.3.1 Purpose. This test method specifies a procedure for testing the immunity of electrical / electronic devices to electrical transients on other than supply lines (I/O lines).

3.2.1.3.3.2 Test Equipment. The test equipment shall comply with ISO 7637-3.

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

- All wires (including power supply lines) shall be routed inside the coupling clamp if not otherwise stated in the test plan.
- Use only test pulse 3a and 3b.

3.2.1.3.3.4 Test 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.

3.2.1.4 Electrostatic Discharge, Component Tests.

3.2.1.4.1 Electrostatic Discharge, Test during Operation of the Device (Power On Mode).

3.2.1.4.1.1 Purpose. This test method specifies a procedure for testing the immunity of components located within the occupant space or trunk (e.g. CD player, switches) of the vehicle and intended to be accessible to the occupant to electrostatic discharge while the device is powered.

3.2.1.4.1.2 Test Equipment. The test equipment shall comply with ISO 10605 with the following deviation:

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

- The risetime requirement for ESD simulator air discharge verification shall be ≤ 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.

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

  1 the contact discharge method (contact discharge tip) and the 330 pF capacitor

  2 the air discharge method (air discharge tip) and the 330 pF capacitor

- According to the test sequence in Table 7 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 7.

Note: 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 of the ESD simulator discharge energy that the instrumentation would not normally experience.

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

Table 7: Test Sequence for ESD Component Tests during Operation of the Device.

Test number	Type of discharge	Test voltage level	Minimum number of discharges at each polarity
1	Air discharge (C = 330 pF, R = 2 kΩ)	±4 kV	5
2	Contact discharge (C = 330 pF, R = 2 kΩ)	±4 kV	5
3	Air discharge (C = 330 pF, R = 2 kΩ)	±6 kV	5
4	Contact discharge (C = 330 pF, R = 2 kΩ)	±6 kV	5
5	Air discharge (C = 330 pF, R = 2 kΩ)	±8 kV	5
6	Contact discharge (C = 330 pF, R = 2 kΩ)	±8 kV	5
7	Air discharge (C = 330 pF, R = 2 kΩ)	±15 kV	5
8	Air discharge (C = 150 pF, R = 2 kΩ)	±25 kV	5

3.2.1.4.2 Electrostatic Discharge, Remote Inputs/Outputs.

3.2.1.4.2.1 Purpose. 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 which are accessible by vehicle occupants.

3.2.1.4.2.2 Test Equipment. The test equipment shall comply with ISO 10605 with the following deviation:

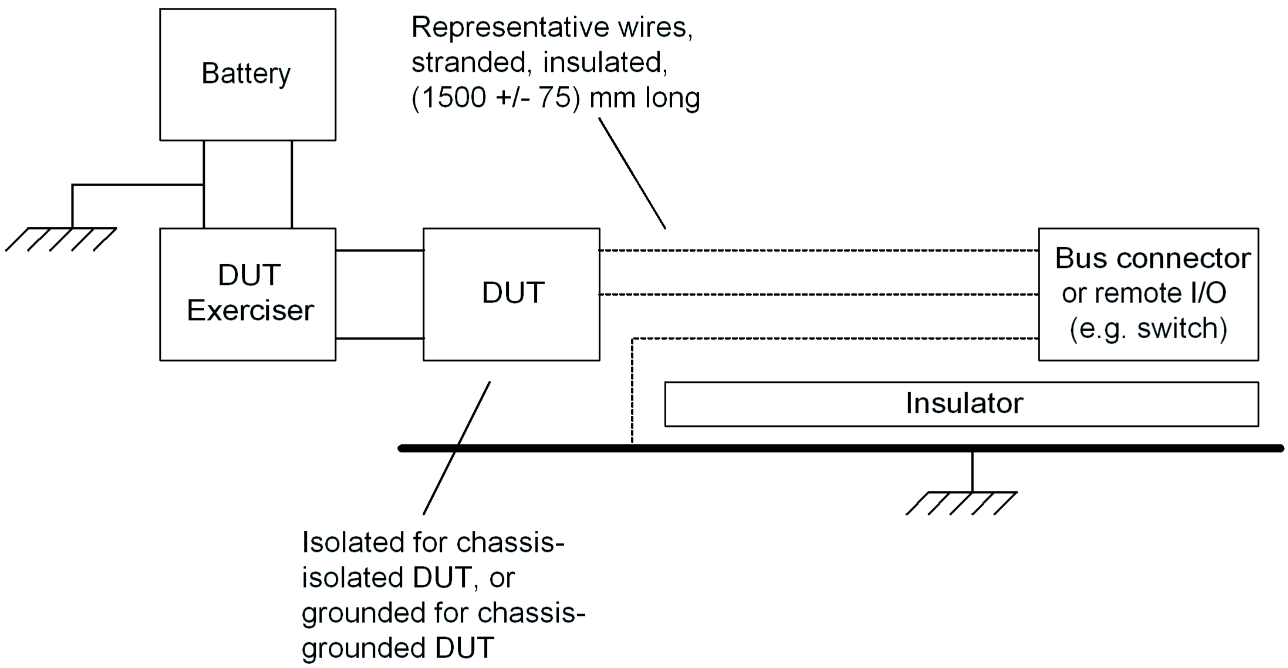
The ESD simulator waveform verification shall comply with ISO 10605 with the following exceptions:

- The risetime requirement for ESD simulator air discharge verification shall be ≤ 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.

3.2.1.4.2.3 Test Procedure. 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.

The test setup shall be configured according to Figure 6.

Figure 6: ESD Test Setup for Remote Inputs/Outputs



a The DUT and the test connector shall be separated by a distance of (1500 ±75) mm. Production representative or stranded insulated wires shall be attached between them, and shall only be connected to the appropriate pins of the DUT and the test connector or remote I/O (e.g. switch).

b If the DUT is a chassis mounted component in the vehicle, it shall be placed or attached onto the conductive ground plane surface during testing. If the DUT is chassis-isolated in the vehicle, then a representative isolation block shall be used under it during testing. A battery with (13.5 +0.5/-1) V shall be used to power the DUT during the ESD discharging events.

c The wires between the DUT and connector shall be placed on a clean, non-hygroscopic insulator. This insulator shall be placed onto the conductive plane. The ground plane shall be attached to the negative terminal of the battery and to building ground or as otherwise defined in the test plan.

d If the test applies to a DUT's data communication bus/connector, it shall be tested in an unloaded condition (i.e. no node load condition). In this case the bus connector pins shall be extended by a 2.5 cm long solid core wire in order to enable the discharge to a specific pin.

e After each discharge, any remaining charge of the test connector pins shall be bled off using a 1 MΩ resistor.

f The ESD test levels, the polarity, and the order of tests shall follow Table 8. At each voltage level, test all discharge points of the test connector at both polarities.

Test number 8 is not applicable to bus connectors.

Performance of the DUT shall be verified after each series of discharges at a specific voltage level. 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.

3.2.1.4.3 Electrostatic Discharge, Handling of Devices.

3.2.1.4.3.1 Purpose. This test method specifies a procedure for testing the sensitivity of electrical / electronic devices to electrostatic discharge during handling.

3.2.1.4.3.2 Test Equipment. The test equipment shall comply with ISO 10605 with the following deviation:

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

- The risetime requirement for ESD simulator air discharge verification shall be ≤ 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.

3.2.1.4.3.3 Test Procedure. Maintain the ambient temperature at (23 ±3) °C and the relative humidity from 20 % to 40 % (20 °C and 30 % relative humidity preferred) during testing.

Test each connector pin, case, button, switch, display, case screw and case opening of the DUT that is accessible during handling using:

- direct contact discharge method
- air discharge method

according to the test sequence in Table 9.

3.3 Test of Design and Construction. Not applicable.

3.4 Documentation.

3.4.1 Test Results. 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/or 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 or description of the harness.
- Equipment calibration data, if required by the test plan, unless available in the facility records.

Table 8: Test Sequence for ESD Tests of Remote Inputs/Outputs

Test number	Type of discharge	Test voltage level	Minimum number of discharges at each polarity
1	Air discharge (C = 330 pF, R = 2 kΩ)	±4 kV	5
2	Contact discharge (C = 330 pF, R = 2 kΩ)	±4 kV	5
3	Air discharge (C = 330 pF, R = 2 kΩ)	±6 kV	5
4	Contact discharge (C = 330 pF, R = 2 kΩ)	±6 kV	5
5	Air discharge (C = 330 pF, R = 2 kΩ)	±8 kV	5
6	Contact discharge (C = 330 pF, R = 2 kΩ)	±8 kV	5
7	Air discharge (C = 330 pF, R = 2 kΩ)	±15 kV	5
8	Air discharge (C = 150 pF, R = 2 kΩ)	±25 kV	5

Table 9: Test Sequence for ESD Component Tests, Handling of Devices.

Test number	Type of discharge	Test voltage level	Minimum number of discharges at each polarity
1	Contact discharge (C = 150 pF, R = 2 kΩ)	±4 kV	5
2	Contact discharge (C = 150 pF, R = 2 kΩ)	±6 kV	5
3	Air discharge (C = 150 pF, R = 2 kΩ)	±8 kV	5

3.4.2 Deviations from Test Procedure. Deviations from the requirements of the test procedures shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports etc.

4 Verification

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 responsible GM 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 responsible GM Department and the supplier.

5 Test of Provisions for Shipping

Not applicable.

6 Notes

6.1 Glossary. Not applicable.

6.2 Acronyms, Abbreviations and Symbols.

ALDL	Assembly Line Diagnostic Link
AN	Artificial Network
AWG	American Wire Gauge
B+	Battery Plus
CBCI	Common Mode Bulk Current Injection
CE	Conducted Transient Emissions
CI	Conducted Transient Immunity
CTS	Component Technical Specification
CW	Continuous Wave
dBC	dB relative to the Carrier
DBCI	Differential Mode Bulk Current Injection
DC	Direct Current
DUT	Device under Test
ECM	Electronic Control Module
EMC	Electromagnetic Compatibility
ESD	Electrostatic Discharge
GM	General Motors
GMNA	General Motors North America
GMW	General Motors Worldwide
I/O line	Input/Output line
IEC CISPR	International Electrotechnical Commission Comité International Spécial des Perturbations Radioélectrique (International Special Committee on Radio Interference)
ISO	International Organization for Standardization
ITDC	International Technical Development Center
LISN	Line Impedance Stabilization Network
PCM	Powertrain Control Module
Pk+	Positive Peak
PWM	Pulse Width Modulated
RBW	Resolution Bandwidth
RE	Radiated Emission
RF	Radio Frequency
RI	Radiated Immunity
RMS	Root Mean Square
SAE	Society of Automotive Engineers
VSWR	Voltage Standing Wave Ratio
VTS	Vehicle Technical Specification

7 Additional Paragraphs

Not applicable.

8 Coding System

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

GMW3100

Where

GMW	Validation Area (GM Worldwide)
3100	Sequential number
	Class: General Specification
	Type: All Vehicle
	Category: Electrical Architecture

Example:

"Test of requirements to GMW3100"

9 Release and Revisions

9.1 Release. The specification was first approved in APR 1999.

It has been prepared by the GM Global EMC Committee.

9.2 Revisions.

Rev.	Date	Description (Org.)
A	APR 1999	New, was also "called revision 1" (ITDC)
B	JUN 2000	Editorial, was also "called revision 1" (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: Wiring harness length changed for conducted emissions with LISN, GPS frequency range changed. Radiated Immunity: Test frequencies changed, forward power instead of net power for 0.4 to 10 GHz, BCI wiring harness length and probe position changed, reverberation mode tuning added, reverberation mode stirring will be faded out. Conducted Immunity: Pulse 6, 7b and 8 eliminated, pulse 4 voltage detailed, pulse 5 parameters changed. Electrostatic Discharge: Number of discharges reduced, trunk position added, wiring harness length changed for remote inputs/outputs, Handling of Devices rewritten, Packaging recommendations eliminated. Test reports: Photographs required. All paragraphs: Editorial changes and clarifications (ITDC)

Appendix A

A.1 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 commonmode 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.

Appendix 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 according to Section 3.2.1.2.2.3 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.

Note: 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 7. 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 7.

v At the lowest test frequency (f_S = 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 10.

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 (P_{MaxRec} ,P_{AveRec}), the maximum field strength for each axis of the electric field probe ($E_{Max\ x}$, $E_{Max\ y}$, $E_{Max\ z}$), and the average input power (P_{Input}) 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 (P_{MaxRec}) for proper average data collection.

Note: P_{Input} is the forward power averaged over one tuner rotation. The number of samples used to determine P_{Input} 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 10 until the frequency is at least 4000 MHz (10 f_S).

ix Repeat steps v. through vii. for each of the eight probe locations shown in Figure 7 and for eight antenna locations until 4000 MHz (10 f_S). 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 f_S), 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 10. 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 f_S, and 9 rectangular components above 10 f_S) to the square-root of the average input power using the data from step vii.:

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

where

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

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

P_{Input}= average input power to transmit antenna during the tuner rotation at which $E_{Max\ x,y,z}$ was recorded

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

$$\langle\overleftrightarrow{E}_x\rangle_8 = \left(\sum \overleftrightarrow{E}_x\right)/8$$
$$\langle\overleftrightarrow{E}_y\rangle_8 = \left(\sum \overleftrightarrow{E}_y\right)/8$$
$$\langle\overleftrightarrow{E}_z\rangle_8 = \left(\sum \overleftrightarrow{E}_z\right)/8$$

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

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

i = 1,2, ... 8 (number of probe locations)

Note: < > indicates arithmetic mean, i.e.,

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

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 f_S (4000 MHz), replacing 8 with 3.

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

xvi For each frequency below 10 f_S, 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:

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

where

i = 1,2, ... 8 (number of probe locations)

n = number of measurements

$\overleftrightarrow{E}_i$= maximum normalized electric field probe measurement

$\left\langle\overleftrightarrow{E}\right\rangle$= arithmetic mean of the normalized electric field measurements

α = 1.06 for n ≤ 20 and 1 for n > 20

σ = standard deviation for a given axis (x, y, or z)

Example for the x-axis

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

where

i = 1,2, ... 8

$\overleftrightarrow{E}_{ix}$= maximum normalized electric field probe measurement of x axis

$\left\langle\overleftrightarrow{E}_x\right\rangle$= arithmetic mean of normalized axes from all eight measurement locations

Example for all axes:

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

where

i = 1,2, ... 8

$\overleftrightarrow{E}_{ix,y,z}$= maximum normalized electric field probe measurements of all axes (x, y, and z)

$\left\langle \overleftrightarrow{E} \right\rangle_{24}$ = arithmetic mean of normalized $E_{Max\ x,y,z}$ 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:

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

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:

$$ACF = \left\langle \frac{P_{AveRec}}{P_{Input}} \right\rangle_{8\ for\ \leq 10\ f_s,\ 3\ for\ \geq 10\ f_s}$$

where

P_{Input} is the average input power from B.1.1.vii. for the location at which the average received power P_{AveRec} 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:

$$IL = \left\langle \frac{P_{MaxRec}}{P_{Input}} \right\rangle_{8\ for\ \leq 10\ f_s,\ 3\ for\ \geq 10\ f_s}$$

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 f_s, three > 10 f_s). 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.

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 (f_s = 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 10 (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 (P_{MaxRec}, P_{AveRec}), and the average input power (P_{Input}) 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 (P_{MaxRec}) for proper average data collection.

v Repeat step iv. for each frequency defined in Section 3.2.1.2.

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

P_{AveRec}= average received power over one tuner rotation from step vii.

P_{Input}= 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 P_{AveRec} 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 GMW3097 Section 3.2.1.2.2.1

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

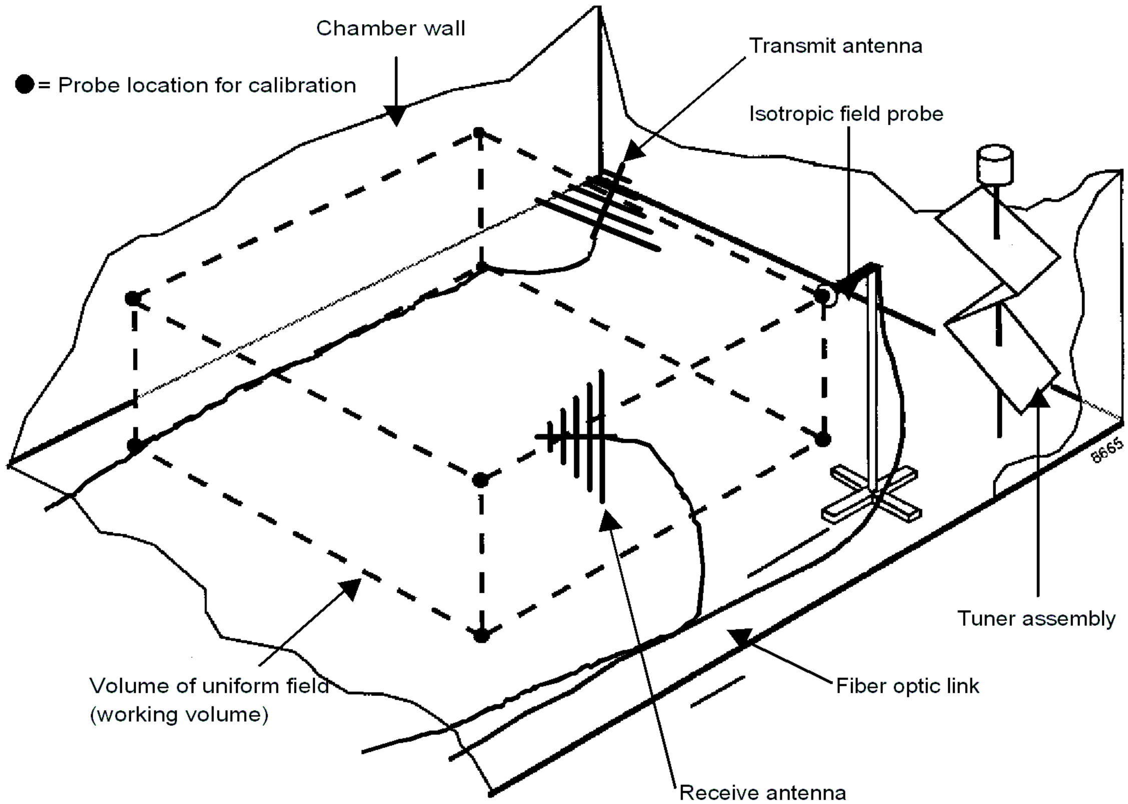
f = the test frequency (Hz)

iii If τ > (0.4 * the pulse width) given in GMW3097 Section 3.2.1.2.2.1 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 10: Independent samples and frequencies

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

Figure 7: Reverberation Test Configuration (Mode Tuning)



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