SAE International

SURFACE VEHICLE STANDARD

SAE J551-11 MAR2010

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Superseding	J551-11 SEP2000

Vehicle Electromagnetic Immunity - Off-Vehicle Source

RATIONALE

J551-11 is nearly technically identical to ISO 11451-2 and we have concluded that we can accept the differences contained in the ISO document.

FOREWORD

This SAE Standard is similar ISO 11451-2: Road vehicles - Electrical disturbances by narrowband radiated electromagnetic energy - Vehicle test methods - Part 2: Off-vehicle source. Appendix A has been modified in accordance with the concepts of SAE J1812 and SAE J551-1.

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1. SCOPE

This part of SAE J551 specifies off-vehicle radiation source test methods and procedures for testing passenger cars and commercial vehicles.

Two methods for calibrating electromagnetic fields are defined in the document: a substitution method and a closed-loop method. The substitution method is the method most commonly used.

SAE J551-1 specifies general, definitions, practical use, and basic principles of the test procedure.

2. REFERENCES

2.1 Applicable Publications

The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J551-1 Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicle and Devices (60 Hz to 18 GHz)

SAE J1812 Function Performance Status Classification for EMC Susceptibility Testing of Automotive Electronic and Electrical Devices

2.1.2 ISO Publication

Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 10 305 Road vehicles - Generation of standard electromagnetic fields for calibration of power density meters - 20 kHz to 1000 MHz (equivalent to NBSIR 75-804 - available from NIST)

ISO 11451-2 Road vehicles - Electrical disturbances by narrowband radiated electromagnetic energy - Vehicle test methods - Part 2: Off-vehicle source

3. TEST CONDITIONS

See SAE J551-1 section 6 for additional guidance on test conditions

3.1 Test Temperature and Supply Voltage

Heat is generated in the test facility when the vehicle is operated during the performance of the test. Sufficient cooling must be provided to ensure that the engine does not overheat.

The ambient temperature in the test facility must be recorded if it is outside the range of 23 °C ± 5 °C.

For tests that require the vehicle engine to be running, the electrical charging system shall be functional. For tests where the vehicle engine is not required to be running, the battery voltage shall be maintained above 12.2 V and 24.4 V for 12 V and 24 V systems, respectively.

3.2 Frequency Range

The applicable frequency range of this test method is 100 kHz to 18 GHz. Testing over the full frequency range may require different field-generating devices. This does not imply requiring testing of overlapping frequency ranges.

3.3 Modulation

See SAE J551-1.

3.4 Dwell Time

See SAE J551-1.

3.5 Frequency Steps

See SAE J551-1.

3.6 Test Signal Quality

See SAE J551-1.

3.7 Threshold of Response

See SAE J551-1.

3.8 Test Severity Levels

Tests shall be conducted in both horizontal and vertical polarizations over the test frequency range. Any exceptions to this practice shall be specified in the test plan. The user shall specify the test severity level(s) over the frequency range. Suggested test severity levels are included in of this document. These test severity levels are expressed in terms of equivalent root-mean-square (RMS) value of an unmodulated wave.

4. TEST INSTRUMENT DESCRIPTION AND SPECIFICATION

The test consists of generating radiated electromagnetic fields by using antenna sets with radio frequency (RF) sources capable of producing the desired field strengths over the range of test frequencies. The fields are monitored with small probes to ensure proper test levels. To reduce testing error, the vehicle operation under test is usually monitored by optical couplers.

4.1 Absorber-Lined Chamber

The objective of an absorber-lined chamber is to create an indoor electromagnetic compatibility testing facility which simulates open field testing. The chamber is lined with absorbing material on as many surfaces in the chamber as possible to minimize reflections and resonances. The design objective is to reduce the reflectivity in the test area to –10 dB or less.

The size, shape, and construction of an absorber-lined chamber can vary considerably. An example of a rectangular chamber is shown in Figure 1. The chamber shape is a function of the types of tests to be performed, the size of vehicle to be tested, and the frequency range to be covered. Basically, an absorber-lined chamber consists of a shielded room with absorbing material on its internal reflective surfaces (optionally floor excepted). The minimum size of the room is determined by the size of the test region needed, the size of the field generation device, and the clearances needed between them and the largest vehicle that is to be tested. To create the test region, the absorber, field-generation system, and chamber shape are selected to reduce the amount of extraneous energy in the test region below a minimum value which will give the desired measurement energy.

A frequency range of 20 MHz to 18 GHz has been achieved in some chambers but because of absorber material sizes required for 20 MHz cutoff, several absorber-lined facilities have been designed with cutoff frequencies of 200 MHz or greater. Testing below cutoff is then accomplished using customized antennas and specialized methods (see 4.2.1).

The vehicle is operated during the performance of this test generating heat in the enclosed chamber. Sufficient cooling must be provided via chamber air conditioning and cooling of the radiator to ensure that the engine does not overheat.

4.2 Instrumentation

4.2.1 Field-Generating Device

The field-generating device may be an antenna or a Transmission Line System (TLS).

The construction and orientation of any field-generating device shall be such that the generated field can be polarized in the mode called out in the test plan.

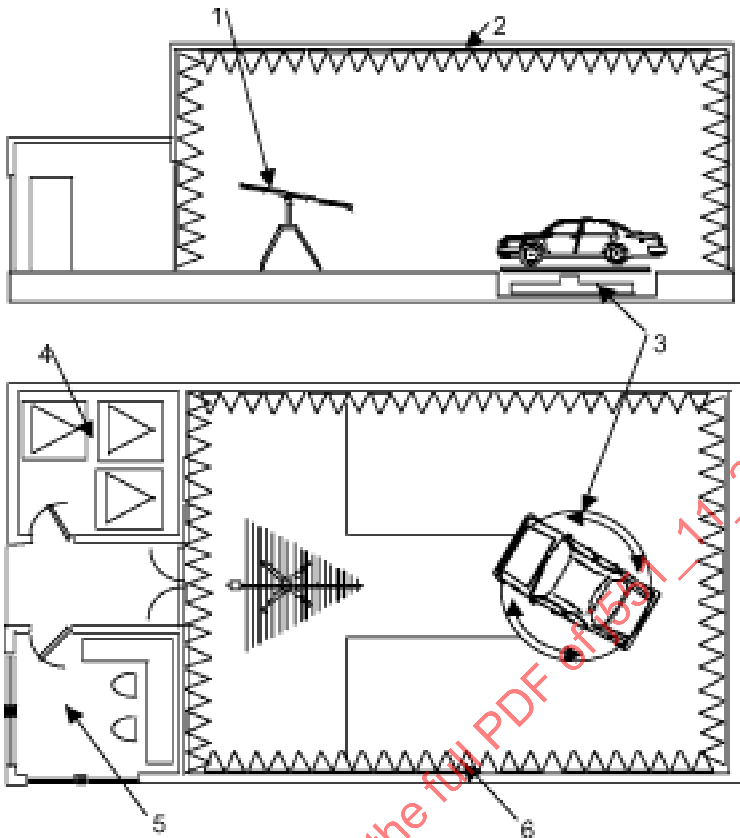
The TLS generating device may have to be custom designed. An example of a parallel plate TLS is shown in Figure 2. An example of equipment block diagram is shown in Figure 3.

4.2.2 DUT Monitor

Test equipment, hardened to the test power levels, required to monitor the operation of the DUT shall be coupled to the control center by fiber-optic links or high-resistance leads.

4.2.3 Field Probes

Field probes should be isotropic. The transmission lines from the probes should be either very high resistance or fiber-optic links.

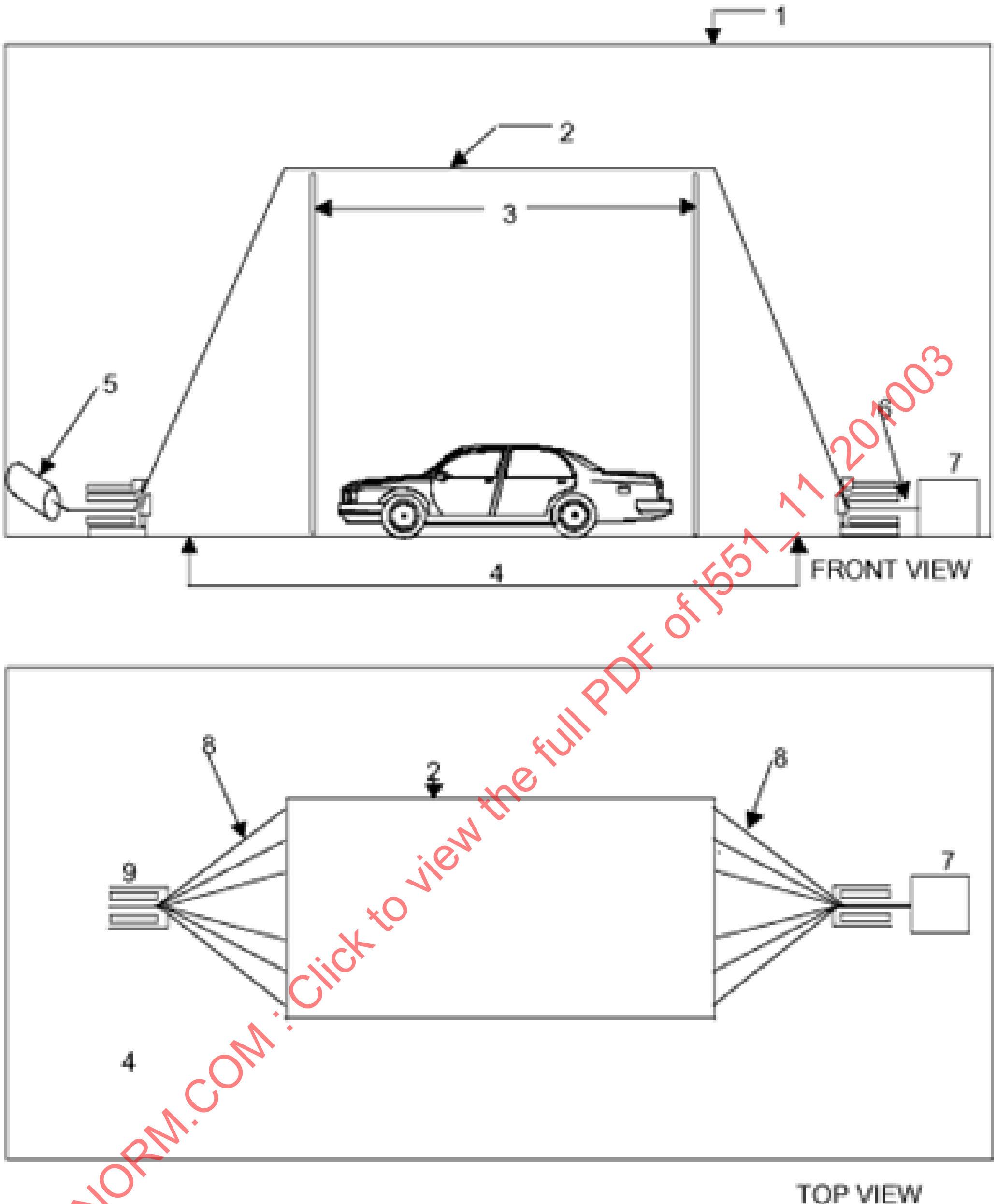


Legend:
1—Antenna
2—Shielded Wall
3—Dynamometer on turntable [1]
4—Amplifier room
5—Instrumentation room
6—RF Absorbers

(Not to scale)

[1] Turntable shown rotatable through ± 180 degrees with two pairs of variable wheelbase rollers to accommodate all vehicle sizes and functions

FIGURE 1 - EXAMPLE OF ABSORBER-LINED CHAMBER



Legend
1—Shielded room (can be absorber lined except for floor)
2—Metal plate
3—Nonmetallic supports
4—Metal floor
5—Signal source feed line (coax)
6—Coaxial cable
7—Load
8—Metal feed lines
9—Signal source feed connection

FIGURE 2 - EXAMPLE OF PARALLEL PLATE TLS

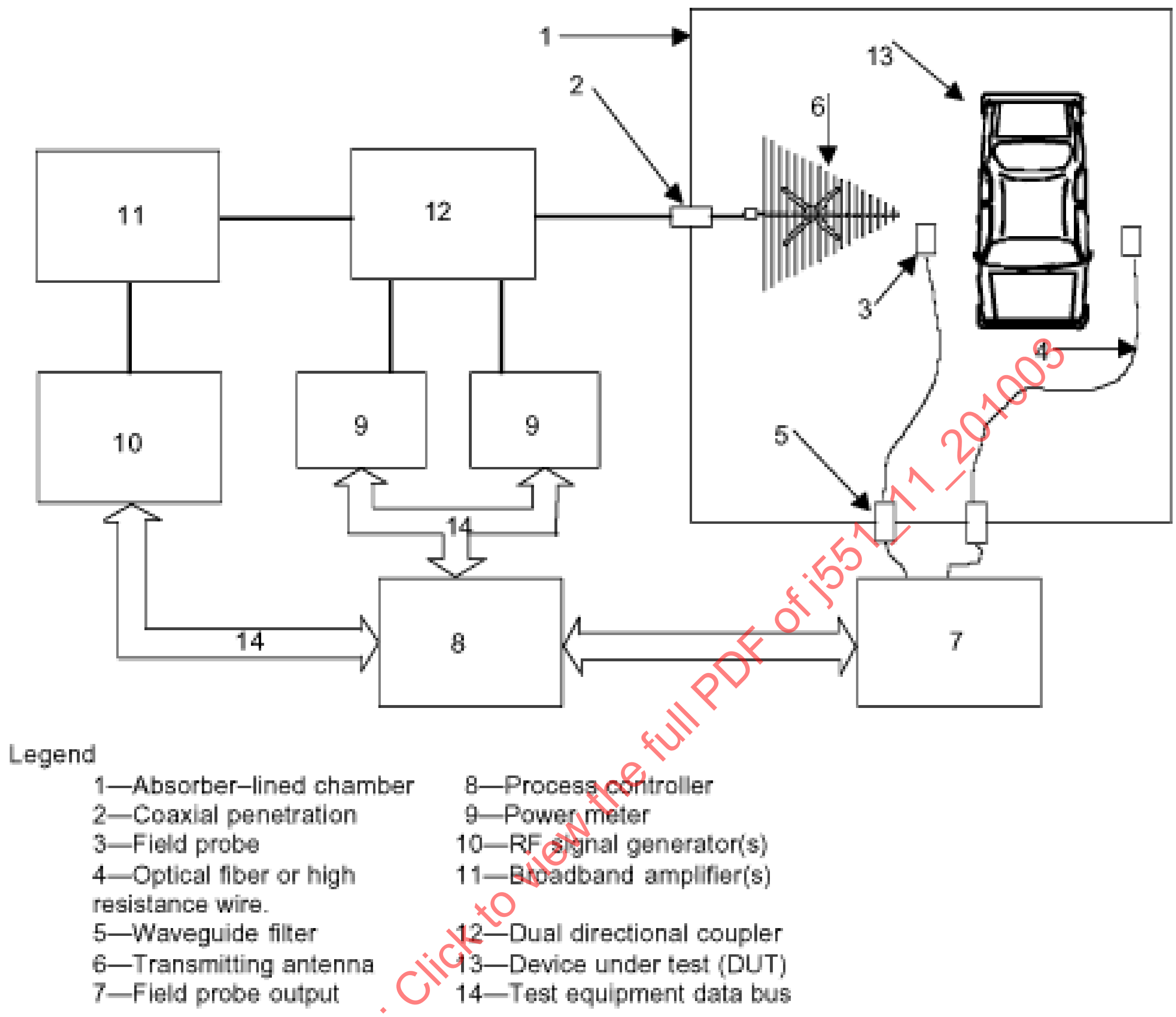


FIGURE 3 - EXAMPLE OF EQUIPMENT BLOCK DIAGRAM

4.3 Test Set-Up

4.3.1 Vehicle Placement

The vehicle shall be placed in the chamber's test area. The test area may contain a dynamometer and/or a turntable (see Figure 1).

4.3.2 Field-Generating Device Location Relative to Vehicle and Chamber

The position(s) of the vehicle relative to the antenna shall be specified in the test plan.

No part of the radiating antenna shall be closer than 0.5 m to the outer body surface of the vehicle.

No part of a TLS, with the exception of the ground plane, shall be closer than 0.5 m to any part of the vehicle.

Any field-generating device which is placed over the vehicle shall extend centrally over at least 75% of the length of the vehicle.

No part of any antenna's radiating elements shall be closer than 0.25 m to the floor.

The radiating elements of the field-generating devices shall not be closer than 0.5 m to any RF absorbent material and not closer than 1.5 m to the wall of the enclosed facility. During testing, there shall be no absorbent material between the transmitting antenna and the vehicle.

NOTE - Depending upon vehicle design, there might be absorber material inside the vehicle.

4.3.3 Test Actuators and Monitors

The DUT shall be operated as required in the test plan by actuators which have a minimum effect on the DUT, e.g., plastic blocks on the accelerator, pneumatic actuators with plastic tubes. Connections to equipment monitoring for electromagnetic interference reactions of the DUT may be accomplished by using fiber optics, or by high-resistance leads. Other types of leads may be used but require extreme care to minimize interactions. The orientation, length, and location of the latter leads shall be carefully documented to assure repeatability of the test results.

5. TEST PROCEDURES

5.1 Test Plan

Prior to performing the tests, a test plan shall be generated which shall include interface test points, DUT mode of operation, DUT acceptance criteria, and any special instructions and changes from the standard test. Every DUT shall be verified under the most significant situations, i.e., at least in stand-by and in a mode where all the actuators can be excited. The test plan shall specify whether to use the closed-loop method or the substitution method.

5.2 Test Method

CAUTION - HAZARDOUS VOLTAGES AND FIELDS MAY EXIST WITHIN THE TEST AREA. CARE SHOULD BE TAKEN TO ENSURE THAT THE REQUIREMENTS FOR LIMITING THE EXPOSURE OF HUMANS TO RF ENERGY ARE MET.

A detailed explanation on basic principles of the test method is given in SAE J551-1.

Place the vehicle in the test area and operate it according to the test plan.

With the field-generating device in the specified polarization, scan each band at the specified field strength in Appendix A noting any events. See 3.3 for recommended modulation modes if not specified in the test plan.

Continue the testing until all modulations, polarizations, frequency bands, vehicle orientations, and antenna locations specified in the test plan are completed. The number of vehicle positions and/or antenna locations may have to be increased with frequency to ensure complete coverage because of the narrow beam width of the high-frequency antennas.

If desired, the threshold immunity level and center frequency can be found. Select the mid-frequency of each response band and slowly increase the transmitted power until a response is seen. Then vary the frequency slightly maintaining constant power to ensure the lowest response level is monitored.

The vehicle can be tested by one of two methods to be agreed to between the supplier and the customer in the test plan.

5.2.1 Substitution Method

The substitution method is based upon the use of net power as the reference parameter used for calibration and test.

In this method, the specific test level (E-field, current, voltage, or power) shall be calibrated prior to the actual testing.

The test with the DUT is then conducted by subjecting the DUT to the test signals based on the calibrated values as predetermined in the test plan.

Measurements using the substitution method can be affected by coupling between the antenna and the DUT as well as by reflected energy. During the test, the net power shall be maintained relative to the calibration point up to a limit of 2 dB increase in forward power.

NOTE 1 - If the forward power has to be increased by 2 dB or more, this shall be indicated in the test report.

NOTE 2 - If the SWR in the test system can be demonstrated to be less than 1.2:1, then forward power may be used as the reference parameter to establish the test.

Place the field generation device at its intended location. Place a calibrated isotropic field probe at the reference point (see 5.2.1.1).

An antenna may be substituted for the isotropic-field probe. In this case, readings shall be taken in three mutually orthogonal directions and the isotropic equivalent field determined.

Measure the field, without the vehicle present, with the field probe or the antenna and record the net power necessary to maintain the field level at the specified test level and antenna polarization.

Place the vehicle in the test area and maintain the measured net power for each frequency and antenna polarization specified in the test plan.

5.2.1.1 Substitution Method Reference Point

The reference point is the point at which the field strength shall be established.

Normally, the facility reference point has to be used. Nevertheless, if the test facility is not able to establish the required field in the test area, then the vehicle reference point can be used.

5.2.1.1.1 The facility reference point is defined as follows:

a. At least 2 m horizontally from the closest part of the antenna phase center or at least 1 m vertically from the radiating elements of a TLS.

b. At the center of the test area.

c. At a height of 1 m ± 0.05 m above the chamber floor for vehicles with roof heights equal or less than 3 m, or 2 m ± 0.05 m for vehicles with roof heights greater than 3 m. Other heights may be specified and measured.

d. Above 200 MHz, the field uniformity over a 1.5 m diameter horizontal plane centered at the reference point should be ±3 dB for at least 80% of the test frequency points.

   NOTE - For existing facilities, this field uniformity requirement may not be met. In those cases, this information should be included in the test report. The user should also ensure good reproducibility of the measurement.

5.2.1.1.2 The vehicle reference point is defined as follows:

a. At least 2 m horizontally from the antenna phase center or at least 1 m vertically from the radiating elements of TLS.

b. On the vehicle's centerline (plane of longitudinal symmetry).

c. At a height of 1 m ± 0.05 m above the chamber floor or 2 m ± 0.05 m for vehicles with roof heights of greater than 3 m. Other heights may be specified and measured.

d. Depending on the vehicle geometry 0.2 m ± 0.2 m behind foremost axle (see Figure 4) or 1 m ± 0.2 m inside the vehicle, measured from the point of intersection of the vehicle windscreen and hood (see Figure 5), whichever results in a reference point closer to the antenna.

e. Above 200 MHz, the field uniformity over a 1.5 m diameter horizontal plane centered at the reference point should be ±3.0 dB for at least 80% of the test frequency points.

   NOTE - For existing facilities, this field uniformity requirement may not be met. In those cases, this information should be included in the test report. The user should also ensure good reproducibility of the measurement.

5.2.2 Closed-Loop Field Leveling Method

This method is different from the substitution method in that during the actual test, the E-field levels, measured by several field probes (usually two is sufficient) distributed over the vehicle, are used to control the signal generator to either increase or decrease the field strength until the test level is achieved. The use of more than one probe is necessary to reduce the effects of standing waves.

Placement of the probes for the closed-loop leveling method is critical to reducing measurement errors. If the probes are placed near a discontinuity, such as a sharp bend or corner of the vehicle, or near a resonant cable or component, the resulting measurement could be in error by a substantial amount.

Place the specified number of field probes 0.3 m ± 0.05 m above the vehicle at the specified locations in the test area. Recommended probe locations are the front, above the center of the hood slot, and test antenna side, adjacent to the "A" pillar[1] of the vehicle (see also 5.2.2.1). Using the indicated field level of the highest reading probe, adjust the signal generator to give the specified field level for each frequency and antenna polarization used in the test.

5.2.2.1 Closed-Loop Reference Points

Either one or both of the following reference points can be used. The selected reference point(s) shall be recorded in the test report.

5.2.2.1.1 Passenger Cars and Light Commercial Vehicles

a. 0.3 m ± 0.05 m above the center of the hood slot

b. 0.3 m ± 0.05 m above the vehicle, adjacent to the "A pillar"

5.2.2.1.2 Buses and Commercial Vehicles

a. In the center, 0.3 m ± 0.05 m above the base of the windshield and 30/40 mm from the edge of the hood

b. Near the "A" pillar, 0.3 m ± 0.05 m above and at the center of an arc 0.3 m ± 0.05 m away from the intersection of the windshield and hood

[1] "A" pillar is the vehicle's metal structure on either side of the windshield.

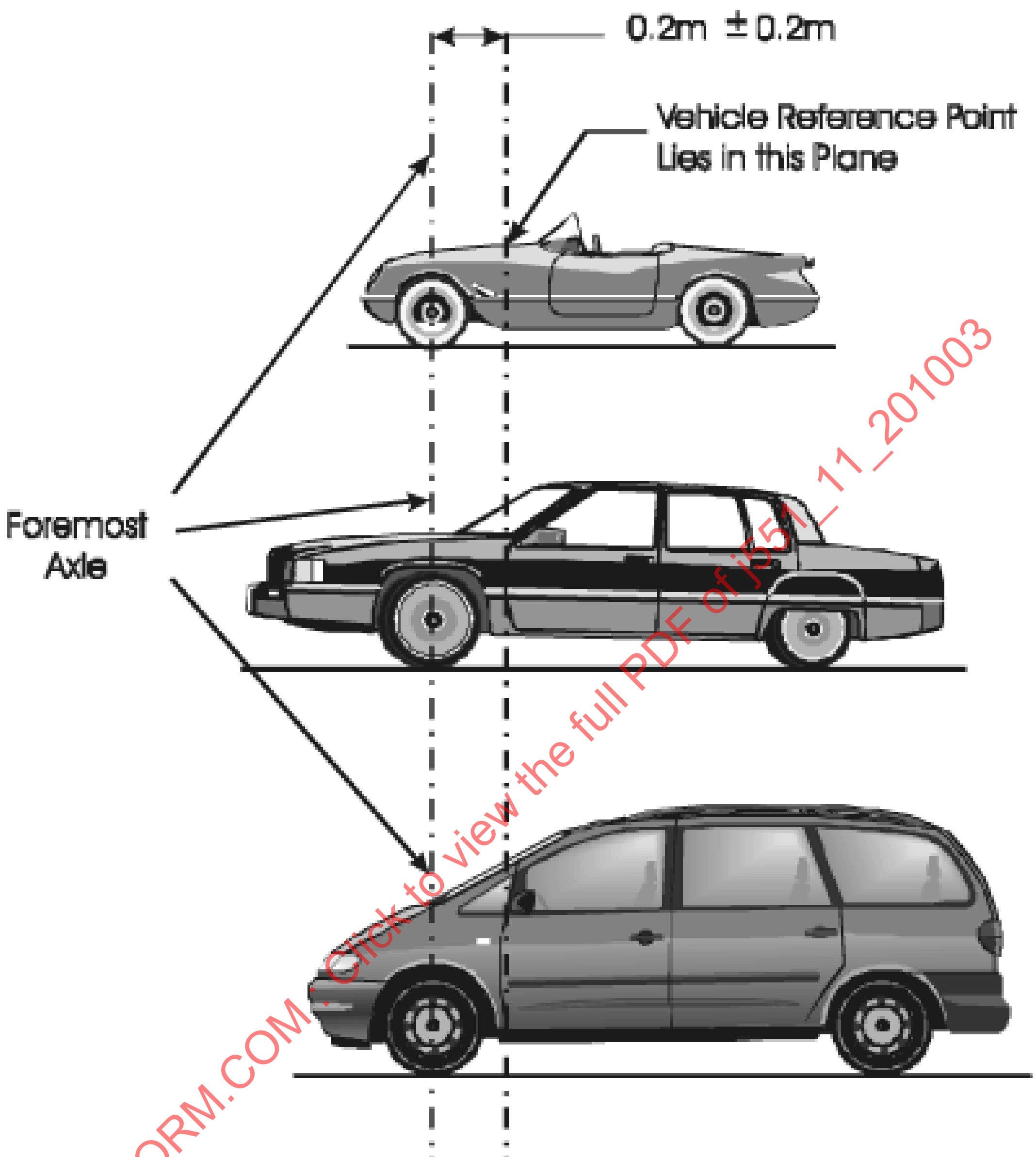


FIGURE 4 - EXAMPLE OF VEHICLE REFERENCE POINT FOR PASSENGER CARS AND LIGHT COMMERCIAL VEHICLES