DaimlerChrysler

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EMC Supplemental Information and Alternative Component Requirements

Foreword

This joint engineering standard is intended to be a supplement to DC-11224 as an acceptance specification for the electromagnetic compatibility (EMC) requirements of electrical and electronic components and systems for DaimlerChrysler (DC) vehicles that reference this standard. **This standard shall be used in combination with DC-11224, EMC Performance Requirements – Component, DC-11223, EMC Performance Requirements – Vehicle and with DC-10615, Electrical System Performance Requirements for Electrical and Electronic Components.** These requirements have been developed to assure compliance with present and anticipated domestic and foreign regulations and customer satisfaction regarding the EMC of vehicle E/E systems.

Changes

Initial issue.

NOTE: The English version of this jointly developed engineering standard is the official document. The German version of this jointly developed engineering standard is the official translation of this document. The official German translation can be found on the DocMaster website. For all other translations, no guarantee can be made as to the accuracy of the technical information.

Contents

1 Scope

This joint engineering standard supplements DC-11224, EMC Performance Requirements – Components. It applies to components and / or subassemblies containing electrical or electronic components for DaimlerChrysler vehicles that specifically reference this standard in their product specification.

1.1 Purpose of the Standard

The purpose of this joint engineering standard is to supplement DC-11224. It defines two alternative component tests as substitutes for tests defined in DC-11224 and one additional test that applies only for certain components and is not intended for regular use.

Additionally this standard collects relevant material that was originally published as informative annexes in DC-10614. This material is intended to provide useful information about the test methods used or EMC testing in general, but is not normative to this standard.

1.2 Use of this Standard

This standard shall be used together with DC-11224. All requirements of DC-11224 apply also to all electrical and electronic components that reference this standard except as otherwise agreed upon between supplier and the appropriate EMC platform team at DaimlerChrysler and specifically stated in the product specification.

Refer to DC-11224 for details.

2 References

ISO 11452-4 2005-04 Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 4: Bulk current injection (BCI)

ISO 11452-7 2003-11 Road vehicles, Electrical disturbances by narrowband radiated electromagnetic energy - Component test methods Part 7 - Direct RF Power Injection

IEC 61967 Integrated Circuits, Measurement of Electromagnetic Emissions, 150 kHz to 1 GHz

SAE J1752 Electromagnetic Compatibility Measurement Procedures for Integrated Circuits

DC-11223, EMC Performance Requirements – Vehicle

DC-11224, EMC Performance Requirements – Components

DS-150, Electronic Module Design Guidelines for Designers to Meet EMC Requirements

DS-151, Electronic Module Design Guidelines for Engineers to Meet EMC Requirements

LP-388C-65, E/E Systems Level Electrical and Electromagnetic Compatibility (EMC) Testing - General Information and requirements for DCTC, Supplier or Third Party EMC Laboratory

3 Terms and Definitions

Refer to DC-11224 for additional definitions.

Direct RF Power Injection. A conducted RF immunity test technique that involves isolating the DUT so that the RF coupling path is controlled. This test is also referred to as single line injection (**SLI**) or Direct Radio Frequency Injection (**DRFI**).

4 Regulated Substances and Recyclability

All materials, procedures, processes, components, or systems must conform to the current regulatory (governmental) requirements regarding regulated substances and recyclability.

End of Main Document
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Annex A (normative)

Pin Conducted RF Emissions (PCE)

A.1 General

This test may be used as an alternative test method to the CISPR 25 conducted RF emissions voltage and current methods of DC-11224, if explicitly agreed upon between the supplier and the responsible DaimlerChrysler EMC engineering department and specifically referenced in the product specification.

Detailed information on emission measurements and instrument settings is given in the Emissions section of DC-11224, which applies for this test as well. For details on test requirements, tolerances and test plans refer to Test Requirements and Functional Status Classification in DC-11224.

Refer to Annex D for special adaptations for CAN and LIN bus testing.

A.2 Requirements

The measurement settings and limit values are defined in Tables A.1, A.2, and A.3. . Table A.1 contains the basic limits for the continuous frequency range. The required frequency bands from Table A.3 by marketing region are given in Table A.2 (on-board receiver bands). All bands from Table A.1 and those from Table A.3 called out in the DUT product specification shall be measured and the limits met.

For CAN or similar data bus lines, emissions up to 85 dBμV, from 500 kHz to 6.3 MHz and the NB values in Table A.3 from 6.3 MHz to 110/200 MHz, are allowed subject to verification that vehicle emission level requirements are met. Also, there shall be no interference with the vehicle receiver attributed to CAN or other data bus emissions at this higher level.

Table A.1: Basic Limit Levels. PCE Method.

Test No.	Frequency Range (MHz)	Peak		Quasi-Peak		Average	
		Level	BW	Level	BW	Level	BW
		dB (μV)	kHz	dB (μV)	kHz	dB (μV)	kHz
CE V 1	30 – 110	40	9/10	-	-		
CE V 2	110 – 200	40	9/10	-	-		

Table A.2: PCE Required Frequency Bands

Markets	Required test bands for broadcast and mobile services – test numbers from Table A.3
ECE	All vehicles: 1, 2, 3, 13, 19 Opt. 1 (if TV available for car line): 16, 17, 18 Opt. 2 (fleet vehicles): 30, 31, 44, 46, 47, 48 Opt. 3 (heavy trucks): 4 - 8, 24 Opt. 4 (add. SW broadcast): 4 -12
NA	All vehicles: 2, 13, 25, 31 Opt. 1 (fleet vehicles): 43, 45 Opt. 2 (if weather band avail.): 14
JP	2, 13, 17, 18
RoW (Rest of World)	2, 13, 31

Table A.3: On-board Receiver Limits. PCE Method.

Test No.	Service or Band	Frequency (MHz)	Peak		Quasi-Peak		Average	
			Level	BW	Level	BW	Level	BW
			dB (µV)	kHz	dB (µV)	kHz	dB (µV)	kHz
Broadcast								
1	LW	0.15 – 0.28	**84 - 66**	9/10	-	-	-	-
2	MW	0.52 – 1.73	**50**	9/10	-	-	-	-
3	SW 49m	5.8 – 6.3	**40**	9/10	-	-	-	-
4	SW 41m	7.1 – 7.6	**40**	9/10	-	-	-	-
5	SW 31m	9.3 – 10.0	**40**	9/10	-	-	-	-
6	SW 25m	11.5 – 12.1	**40**	9/10	-	-	-	-
7	SW 21m	13.6 – 13.8	**40**	9/10	-	-	-	-
8	SW 19m	15.0 – 15.7	**40**	9/10	-	-	-	-
9	SW 17m	17.4 – 17.9	**40**	9/10	-	-	-	-
10	SW 16m	18.9 – 19.1	**40**	9/10	-	-	-	-
11	SW 14m	21.4 – 21.9	**40**	9/10	-	-	-	-
12	SW 12m	25.6 – 26.1	**40**	9/10	-	-	-	-
13	VHF	76 – 108	**30**	9/10	-	-	-	-
14	WB	162.4 – 162.55	**30**	9/10	-	-	-	-
16	TV I	41 – 88	**30**	9/10	-	-	-	-
17	TV II	90 – 108	**30**	9/10	-	-	-	-
18	TV III	174 – 200	**30**	9/10	-	-	-	-
19	DAB	174 – 200	**30**	9/10	-	-	-	-
Mobile Services								
24	Communication	26.5 – 29.7	**40**	9/10	-	-	-	-
25	Communication	30 – 54	**30**	9/10	-	-	-	-
30	4m	65 – 88	**30**	9/10	-	-	-	-
31	2m	140 – 180	**30**	9/10	-	-	-	-
Fleet Mobile Services								
43	Fleet (US)	40 – 44	**20**	9/10		-	-	-
44	Fleet (EU)	84.015 – 87.255	**20**	9/10	-	-	-	-
45	Fleet (US)	140 – 180	**20**	9/10	-	-	-	-
46	Fleet (EU)	147 – 164	**20**	9/10	-	-	-	-
47	Fleet (EU)	167.56 – 169.38	**20**	9/10	-	-	-	-
48	Fleet (EU)	172.16 – 173.98	**20**	9/10	-	-	-	-

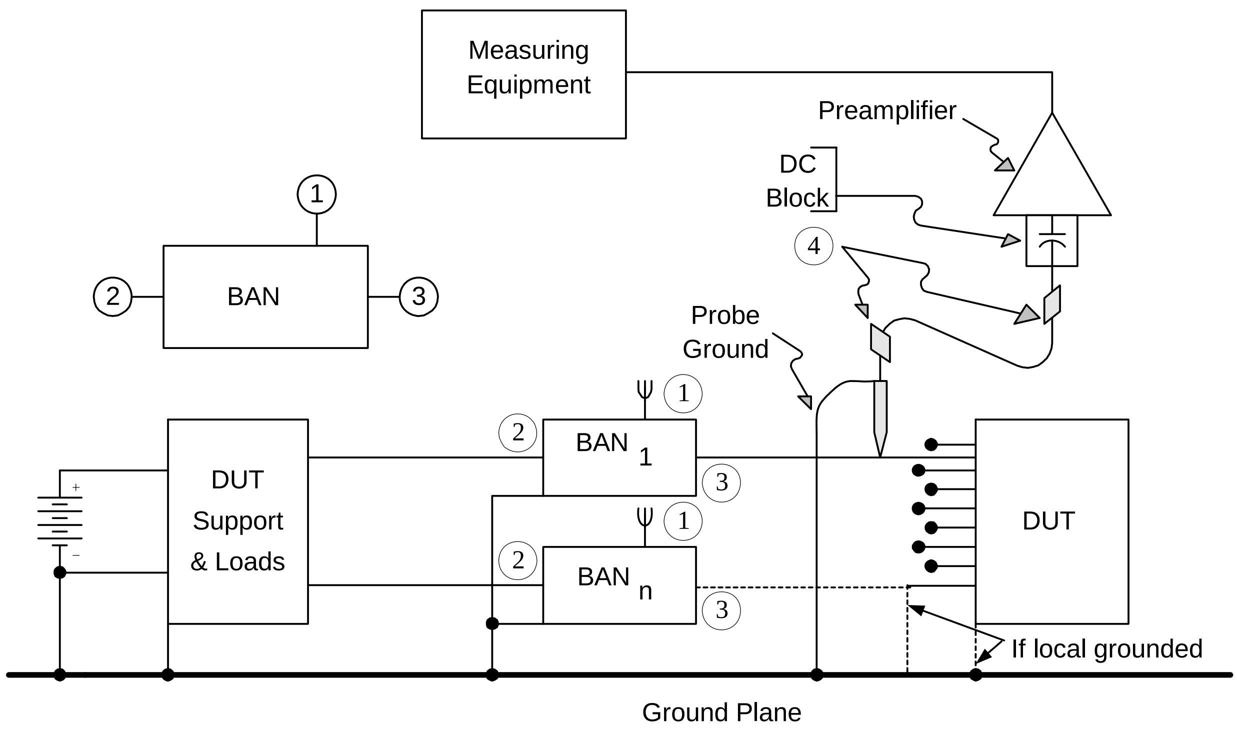
A.3 Test

The DUT shall be powered from a dc supply or storage battery. The voltage shall be within the acceptable range given in DC-11224. If a power supply is used, it shall have low conducted RF emissions that will not affect the test results. If a storage battery is used, its terminal voltage, under load, must not be below 12.0 V dc (or 24.0 V or 36.0 V depending on system voltage). Preferably, the DUT shall be operated with the minimal input and output connections consistent with 'essentially normal' oscillator frequency and logic activity. Necessary inputs and outputs shall be connected to their terminations through appropriate broadband artificial networks (BANs), except where special situations apply. An alternative is to use the full BAN isolated test setup from the DRFI test. For outputs that drive PWM or inductive loads, a representative load shall be connected to the line under test if the typically broadband RF output due to the switching activity is to be evaluated. This loaded characteristic is only to be evaluated if called out in the DUT PF or test plan. The measurement is limited by the dynamic range of the preamplifier. The measurement shall be made using a 500 to 1000 ohms nominal input impedance (10X to 20X) probe (50 ohms output impedance) connected through a blocking capacitor to a preamplifier (if used) and a spectrum analyzer or measuring receiver. A preamplifier may be used for NB measurements from 2 to 110/200 MHz, if needed for measurement to the specified levels. Do not use a preamplifier for BB measurements or below 2 MHz. If a preamplifier is used, assure that the preamplifier is not being overloaded by the DUT signal voltage by switching in 10 dB of attenuation between the probe and the preamplifier and verifying that the signal voltage from the preamplifier to the analyzer is attenuated by 10 dB at 2 MHz. A shielded room is required to provide an ambient level low enough for measurement to the levels specified.

A.4 Test Setup

- Measurements shall be made over the following frequency ranges: 150 kHz to 2 MHz and 2 MHz to 110/200 MHz
- The maximum allowable length of the wiring from the DUT to point 3 on the BAN shall be 150 mm.

For the Pin Conducted Emissions Test setup, refer to Figure A.1.



Key:

1. Low capacitance BNC or similar RF connector
2. Connection to the DUT supply/load circuitry
3. Connection to the DUT
4. Ferrite Clamps at each end of cable

Figure A.1: Pin Conducted Emissions Test Setup

End of Annex A
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Annex B (normative)

Direct RF Power Injection (DRFI) Test

B.1 General

This test is described in ISO 11452-7 and may be used as an alternative test method to the BCI test method of DC-11224, if explicitly agreed upon between the supplier and the responsible DaimlerChrysler EMC engineering department and specifically referenced in the product specification.

The DUT shall be subjected to direct RF power injection, line by line, on all input and output lines specified in the test plan, including unused connector pins. This test applies in the frequency range from 1 to 400 MHz. This test uses a 50 ohm, 10 dB attenuator in the injection network and a broadband isolator (BAN - see Annex F) between each DUT line and its termination, except that low impedance (less than 50 ohms) dedicated sensor or load lines shall be injected at the DUT without using an isolator. As this is a pin by pin test, exercise care to minimize cross coupling from the line under test to adjacent lines. The 10 dB attenuator limits the power at the DUT line under test to one tenth, or less, of the input power and minimizes the effect of reflections caused by the impedance discontinuity at the injection point. Balanced lines shall be injected with a common mode signal. Some lines may be considered balanced over part, but not all, of the frequency range. DUT with multiple grounds are subject to injection on one ground relative to another. If the DUT has a metal case with a local ground, the DUT shall be bonded to the ground plane. Otherwise, the DUT shall be placed on a 50 mm spacer over the ground plane.

If the series inductance of the BAN inhibits data transfer on signal or bus lines, a reduced inductance (increased bandwidth) BAN is available for testing these lines with corresponding modifications to required test frequency ranges. Check in Annex F for details. The test levels in Tables B.1 and B.2 are given as power measured into a 50 ohm load at the output of the 10 dB attenuator.

B.2 DRFI Test Requirements

For Group A, B and C evaluation, the test level is 200mW from 1 to 30 MHz, from 30 to 400 MHz the test levels are split into the basic test level of 100mW and the HIRF test level of 400 mW. For Group D evaluation, the test level is 400mW from 1 to 30 MHz, from 30 to 400 MHz the test levels are split into the basic test level of 200mW and the HIRF test level of 400 mW. The test levels and functional status requirements by frequency range and functional group are specified in Tables B.1 and B.2, the Test Levels are given in Figures B.1 and B.2.

The immunity performance requirements are specified in Tables B.1 and B.2 and the Test Levels in Figures B.1 and B.2.

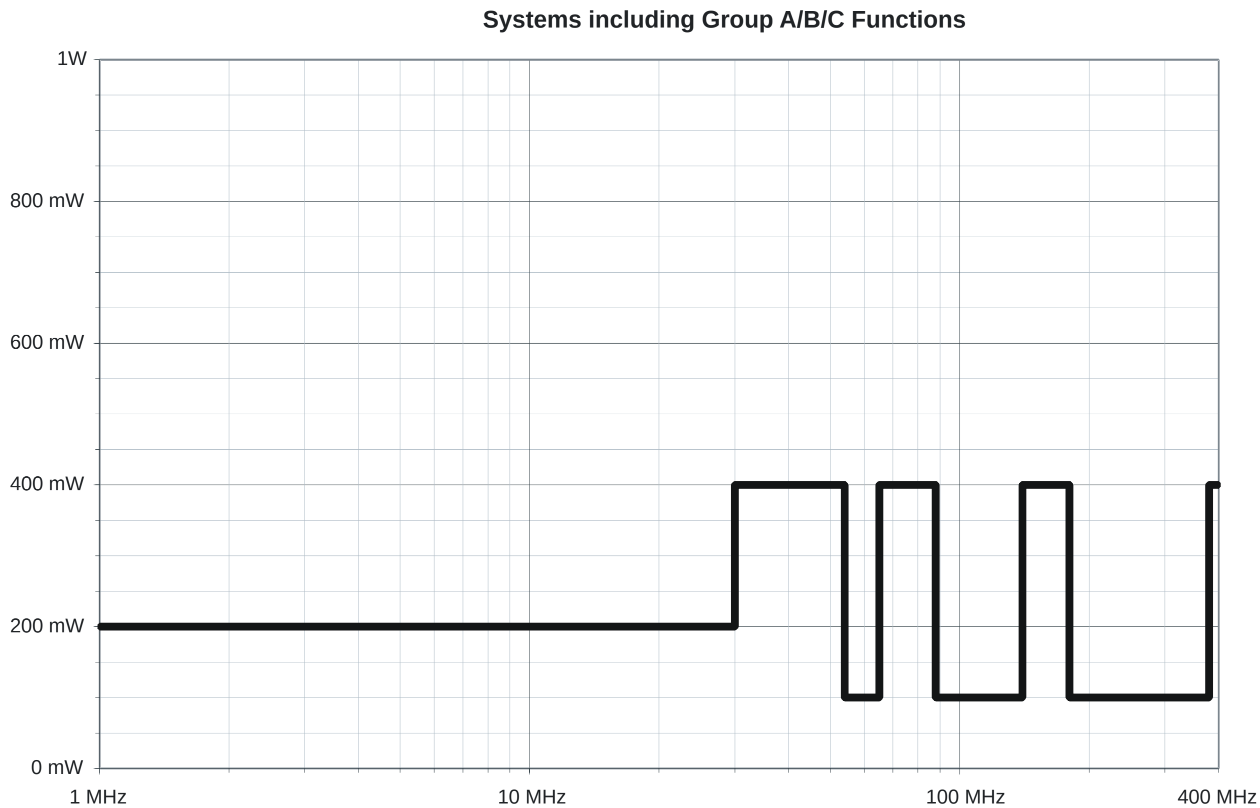


Figure B.1: Test Levels for DRFI Testing, Group A, B and C

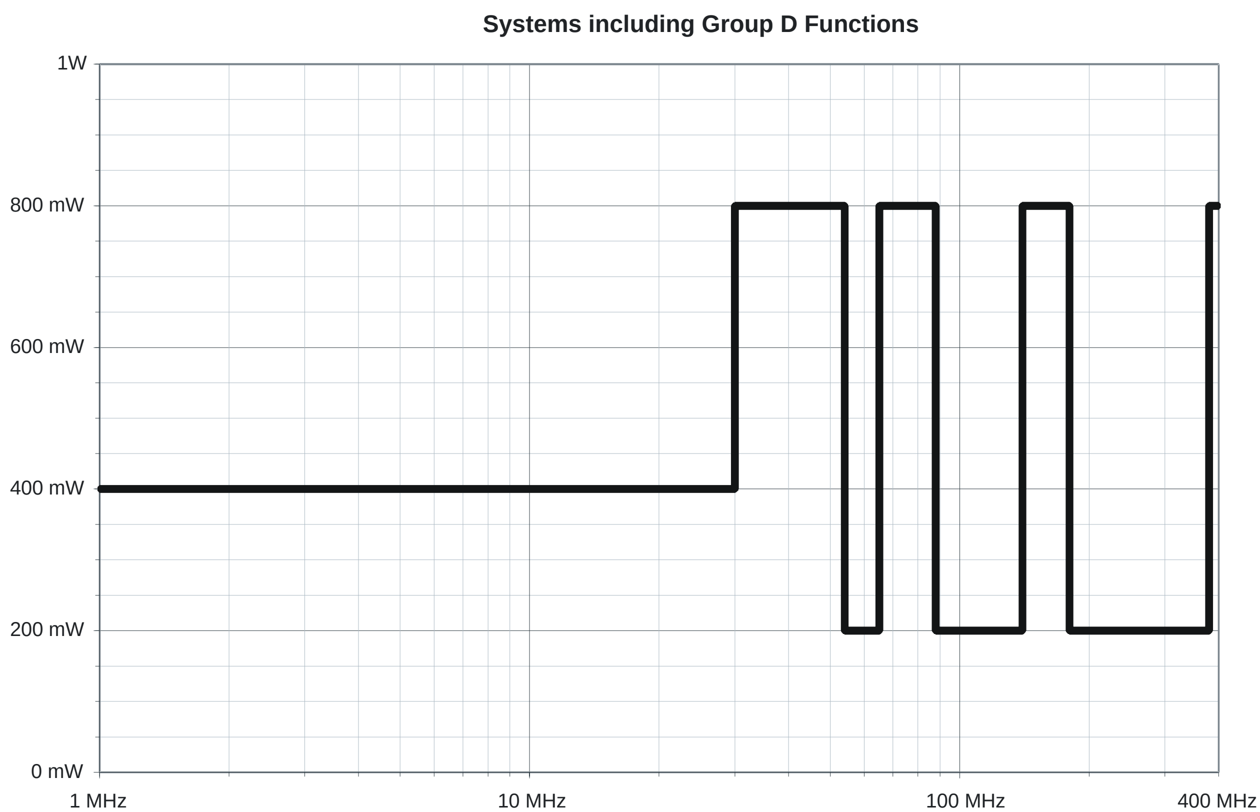


Figure B.2: Test Levels for DRFI Testing, Systems including Group D functions

The top level of Tables B.1 and B.2, shaded gray, is only evaluated if the DUT has a Group D function.

Table B.1: DRFI Immunity Performance Requirements, 1 to 30 MHz for Group A, B, C & D

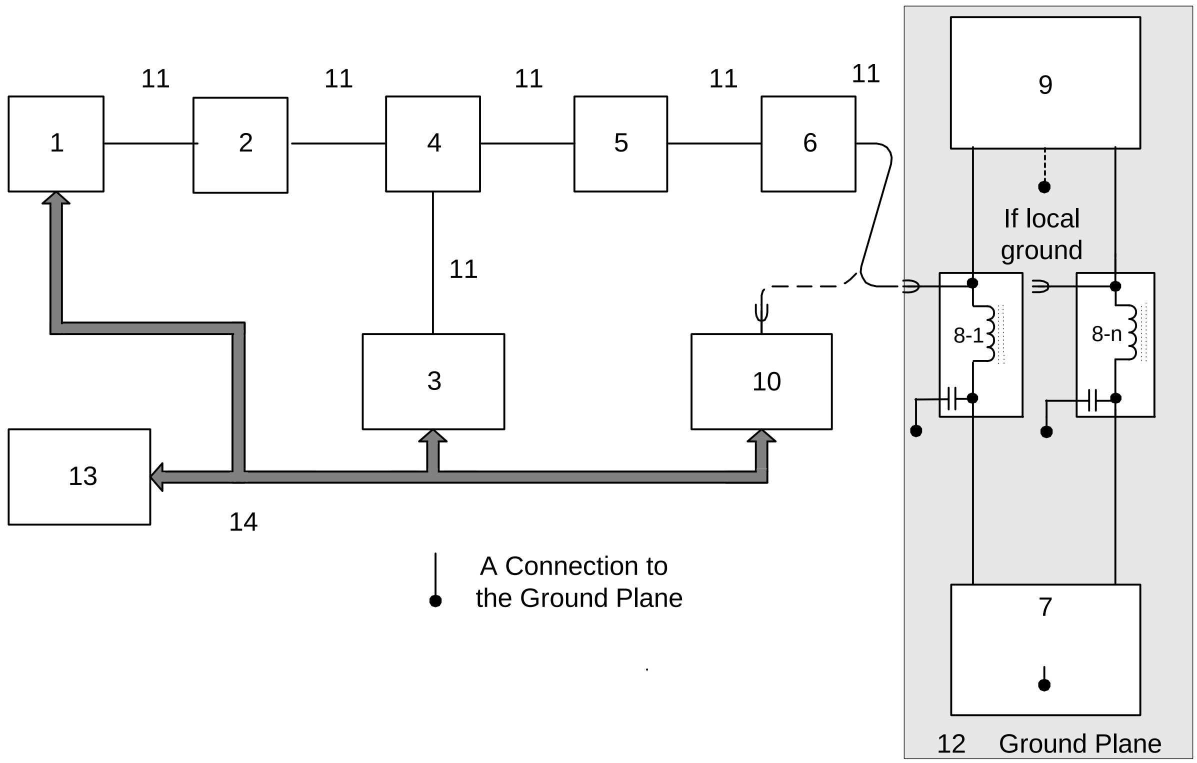
<table>
<tr><th>Test Level [mW]</th><th>Group A Status</th><th>Group B Status</th><th>Group C Status</th><th>Group D Status</th></tr>
<tr><td>> 200 to ≤ 400</td><td>IV</td><td>IV</td><td>III</td><td>II</td></tr>
<tr><td>> 100 to ≤ 200</td><td>III</td><td>III</td><td>II</td><td rowspan="4">I</td></tr>
<tr><td>> 50 to ≤ 100</td><td rowspan="2">II</td><td>II</td><td rowspan="3">I</td></tr>
<tr><td>> 25 to ≤ 50</td><td rowspan="2">I</td></tr>
<tr><td>≤ 25</td><td>I</td></tr>
</table>

Table B.2: DRFI Immunity Performance Requirements, >30 to 400 MHz for Group A, B, C & D

<table>
<tr><th>Test Level [mW]</th><th>Group A Status</th><th>Group B Status</th><th>Group C Status</th><th>Group D Status</th></tr>
<tr><td>> 400 to ≤ 800</td><td>IV</td><td>IV</td><td>III</td><td>II</td></tr>
<tr><td>> 200 to ≤ 400</td><td>III</td><td>III</td><td>II</td><td rowspan="4">I</td></tr>
<tr><td>> 100 to ≤ 200</td><td rowspan="2">II</td><td>II</td><td rowspan="3">I</td></tr>
<tr><td>> 50 to ≤ 100</td><td rowspan="2">I</td></tr>
<tr><td>≤ 50</td><td>I</td></tr>
</table>

B.3 Test Setup

The maximum allowable length of the wiring from the DUT to the BAN shall be 150 mm. Refer to ISO 11452-7 and Figure B.3 for test setup.



Key:

1. RF signal generator
2. RF amplifier(s) (10 to 25 W, typical)
3. Spectrum analyzer or RF power meter
4. RF sampling device (sampling T connector or directional coupler), 50 ohm, 25 W rating, 30 dB isolation
5. Attenuator (Pad) 50 ohm, 10 dB, 10 W
6. DC blocking capacitor
7. Peripherals
8. BANs, one in series with each lead except RF reference ground
9. Device under test
10. RF power meter (for test stand reference level determination)
11. Coaxial transmission line (double shielded or equivalent)
12. Ground Plane
13. Programmable controller and data acquisition equipment
14. Instrumentation data bus

Figure B.3: DRFI Immunity Test Setup

End of Annex B

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Annex C (normative)

Tube Coupler Method

C.1 General

The tube coupler method is appropriate to simulate RF coupling into the wiring harness at high frequencies and can be seen as an extension of BCI to higher frequencies. It is most appropriate for smaller or metal-shielded modules and less appropriate for larger modules with large PCBs like instrument clusters.

This test applies for testing immunity to handheld transmitters operating in the bands GSM 900 and GSM 1800/1900 or for 1.2 and 2.7 GHz radar band testing of selected components.

This test is required only if explicitly agreed to between the supplier and the responsible DaimlerChrysler EMC engineering department and specifically referenced in the product specification.

C.2 Requirements

The immunity requirements are based on environmental data and are adapted to the tube coupler test method through correlation with vehicle data. The immunity performance requirements are specified in Table C.1.

Table C.1: Simulated Handheld Transmitter Immunity Performance Requirements

Band (MHz)	Test Level[1] [mW]	Performance Status Group A	Performance Status Groups B, C and D
824 - 915	200	II	I
1 710 – 1 980	100	II	I
1 200 - 1 400 (with radar pulse)	2000	NA	I (Group D only)
2 700 – 3 200 (with radar pulse)	2000	NA	I (Group D only)

[1] Peak power level, note that the power meter in Figure C.2 will read the average value and for a 12% duty cycle rectangular pulse this will be approximately 12% of the peak value

The power levels given in Table C.1 are the forward power levels into the tube coupler reduced by the insertion loss (L_i) of the tube coupler and measured in dB using the procedure in C.5:

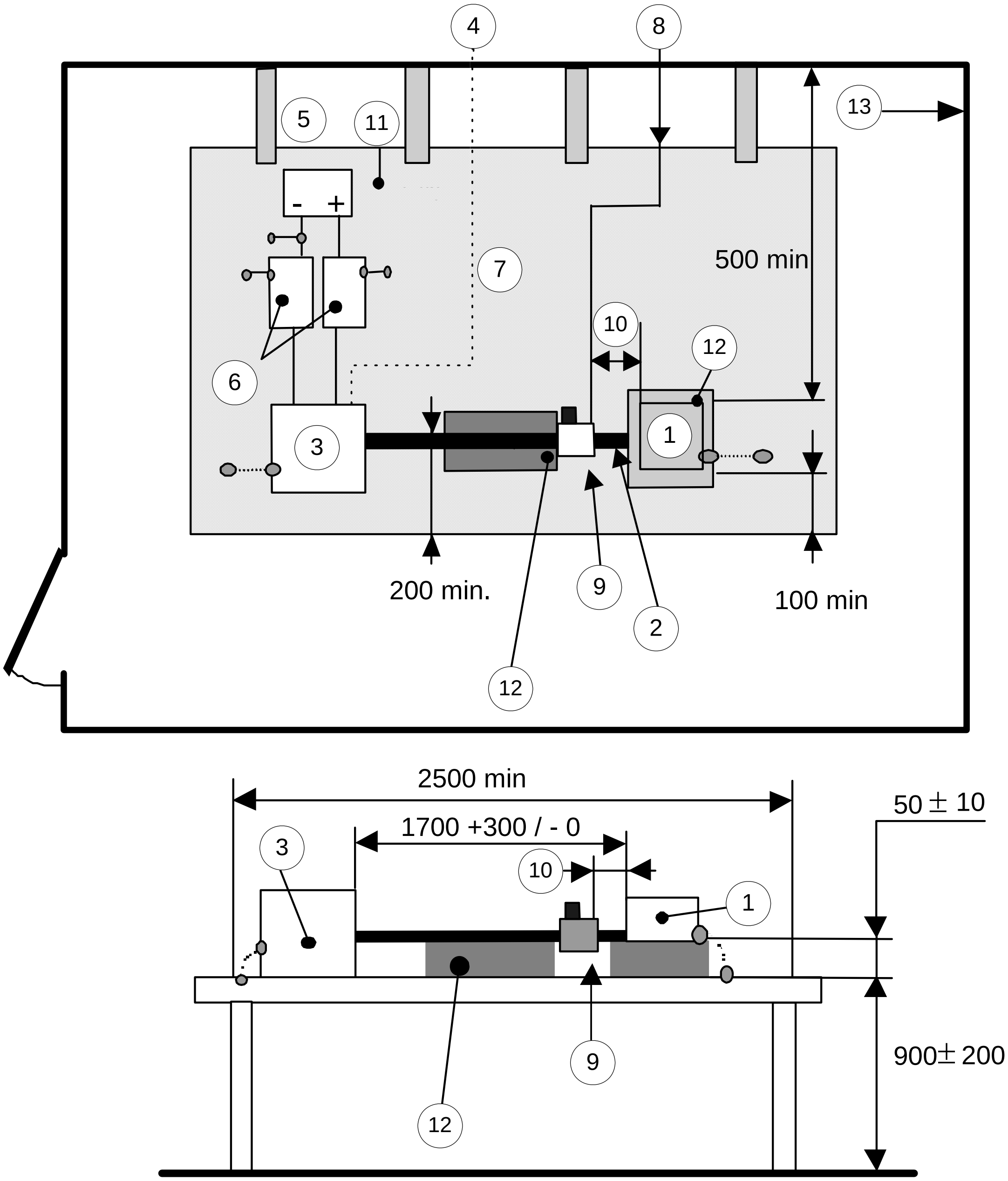
$$P_{test}\Big|_{dBm} = P_{forward}\Big|_{dBm} - L_i\Big|_{dB}$$

or in a linear scale using a transfer factor:

$$P_{test} = P_{forward} \cdot S_{21}$$

C.3 Test Setup

The test setup is essentially the same as for BCI testing (see DC-11224). However, a tube coupler is used instead of a BCI injection probe; refer to Figure C.1 for a schematic diagram of the test setup.



Key:

1 Device under test (connected to ground if specified in the test plan)
2 Wiring harness
3 Load simulator (placement and ground connection according to ISO 11452-4)
4 Stimulation and monitoring system
5 Power supply
6 AN or 50 ohm BAN
7 Optical fibers
8 High frequency equipment
9 Tube coupler (2nd port loaded with 50 ohm)
10 The distance from the DUT to the tube coupler position
11 Ground plane (connected to the shielded room)
12 Insulating support
13 Shielded room

This figure is adapted from ISO WD 11452-4.

Figure C.1: Immunity Test Using the Tube Coupler Method - Test Setup

– A tube coupler appropriate for the frequency range being evaluated shall be used.

– The second input of the tube coupler shall be loaded with 50 ohms.

- Use substitution method with forward power.
- The ground plane shall extend beyond the test setup by at least 100 mm on all sides.
- The distance between the test setup and all other conductive structures (such as the walls of the shielded enclosure) with the exception of the ground plane shall be no less than 500 mm.
- Where part of the system to be tested is normally connected electrically with the vehicle body, this part shall be placed directly on the ground plane and connected to it.
- The test harness shall be 1700 (+ 300, – 0) mm long and routed 50 mm above the ground plane (this harness can also be used for CISPR 25 radiated emission testing).
- The tube coupler shall be located on the test harness 100 mm from the DUT. Where the harness has a number of branches, the test shall be repeated, so that the tube coupler shall be attached around each branch in turn.
- The power supply and peripheral equipment shall be filtered and shielded or located outside the shielded enclosure except for non-susceptible peripherals (such as mechanical switches).
- Wherever possible, production intent vehicle switching devices and sensors shall be used.

C.4 Tube Coupler

A tube coupler is a coaxial system having two input ports that can be clamped around the wiring harness similar to a current probe. It consists of two tubes having the same axis. They form an outer coaxial system having 50 ohms impedance, and the inner tube together with the wiring harness forms an inner coaxial system. Both systems are coupled at the ends of the tubes.

C.5 Calibration

Calibration is done in a method similar to ISO 11452-4 deviating in that the calibration jig shall be designed to form a 150-ohm system together with the tube coupler in the jig. Both ends of the jig shall be loaded by 150 ohms. The calibration setup is shown in Figure C.2.

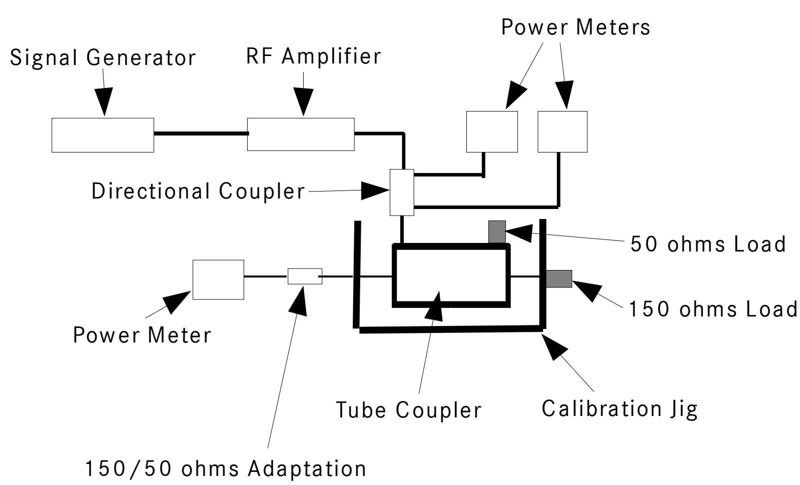


Figure C.2: Immunity Test Using the Tube Coupler Method - Calibration Setup

Calibration involves measuring the transfer factor from port 1 to port 2, i.e. the S-parameter S_{21}. RF power is injected into the system at port 1 using a signal generator and possibly an amplifier if needed (both with 50 ohm output impedance). At port 2, the transferred power through the tube coupler is measured using a power meter or equivalent (with 50 ohms input impedance). Care shall be taken to include the effects of the 150 ohm / 50 ohm matching network. Alternatively, a network analyzer can be used. The insertion loss L_i is given by the negative of the absolute value of S_{21} in dB.

End of Annex C

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Annex D (informative)

EMC Testing and Termination Information for CAN and LIN Bus Systems

D.1 EMC Testing Information for Module / System with CAN Bus

The default CAN Data Bus Functional Classification requirements are:

CAN B:

Bus system communications (vehicle bus disabled due to latching or streaming):	Group C
Fault indicator lamp on, no diagnostic trouble code recorded:	Group C
DUT CAN communication faults (DUT not communicating correctly):	Group C

CAN C:

Bus communications (vehicle bus is disabled due to latching or streaming):	Group C
Fault indicator lamp on, no diagnostic trouble code recorded:	Group C
DUT CAN communication faults (DUT not communicating correctly):	Group C

The above functional classification information is offered as a guideline to be referred to when writing the DUT test plan. The actual CAN bus functional classification requirements depend on the criticality of the message content carried on the bus that the DUT is connected to. For example, if the CAN B bus is used for vehicle immobilizer to allow the vehicle to start, the CAN B bus would be considered Group C for Bus communications (vehicle bus is disabled due to latching or streaming).

For CAN applications, a PC based CANoe (CAN open environment) simulation program, along with the vehicle message matrix (VMM) are required to provide the correct CAN bus traffic. The hardware interface between the PC and the DUT is comprised of a CANcardX (PCMCIA card) and either a CANcab 1041 (CAN B node and cable connecting the CANcardX to the DUT CAN B transceiver) or a CANcab 251 (CAN C node and cable connecting the CANcardX to the DUT CAN C transceiver). The CAN bus shall be monitored for stability via the CANoe tool error frame rate indicator and VMM mismatch indicator.

Note: If a CAN BAN is used to test CAN C lines, the termination requirements of the bus shall be met. (See Annex F for information on BANs.)

Bulk Current Injection (BCI): Either Fiber Optical CAN interface or a Common Mode CAN BAN without Single Point Injection is used, refer to Annex F. This BAN allows the test to be performed from 1 to 250 MHz.

Direct RF Injection: A Common Mode CAN BAN with Single Point Injection is used, refer to Annex F. This BAN allows the test to be performed from 1 to 250 MHz. A 470 pf DC block shall be used to perform the test.

Pin Conducted Emission (PCE): A Common Mode CAN BAN with Single Point Injection is used, refer to Annex F. This BAN allows the test to be performed from 1 to 250 MHz. The CAN bus may be classified as a broadband source below 2.0 MHz. A 470 pf DC block shall be used to perform the test.

Radiated Immunity (TEM CELL): Either Fiber Optical CAN interface a Common Mode CAN BAN without Single Point Injection is used, refer to Annex G. The CAN wiring harness shall be as described in DC-11224, TEM Cell Test.

Radiated Immunity (ALSE - Anechoic Chamber): CAN shall be optically coupled for the test. For testing with a ground plane, the CAN wiring harness shall be as described in DC-11224, BCI (Figure 9). For testing without a ground plane, the CAN wiring harness shall be as described in DC-11224, ALSE without Ground Plane.

D.2 Introduction to CAN Bus Loading

During the EMC testing, if the required loading for CAN BUS and LIN BUS is not provided, the CAN system may not function properly and the test results for both RF immunity and RF emissions may not be reliable. For other special BUS applications, similar information shall be provided by the product engineer. For vehicle level testing, if a component is removed from the testing vehicle, the proper BUS loading may need to be added to substitute for this component. For component level testing, the proper BUS loading shall be used. The detailed loading methods are discussed in this document. Note: all resistors and capacitors are within +/-5% tolerance. All CAN BUS harnesses shall be twisted during the testing (33-50 twists / meter or 1-2 twists / inch).

Optical CAN probes are recommended for EMC testing especially for RF immunity and ESD tests. If a Fiber Optical Interface is used, the length of the fiber shall be controlled to avoid the delay of BUS signals.

The test plan shall provide the information for the component CAN type (B, C, IHS, or LIN) and the function (dominant, non-dominant, etc).

D.3 CAN-B

D.3.1 Typical CAN-B System Layout

Figure D.1 and Table D.1 show the basic layout and internal impedance values for CAN-B.

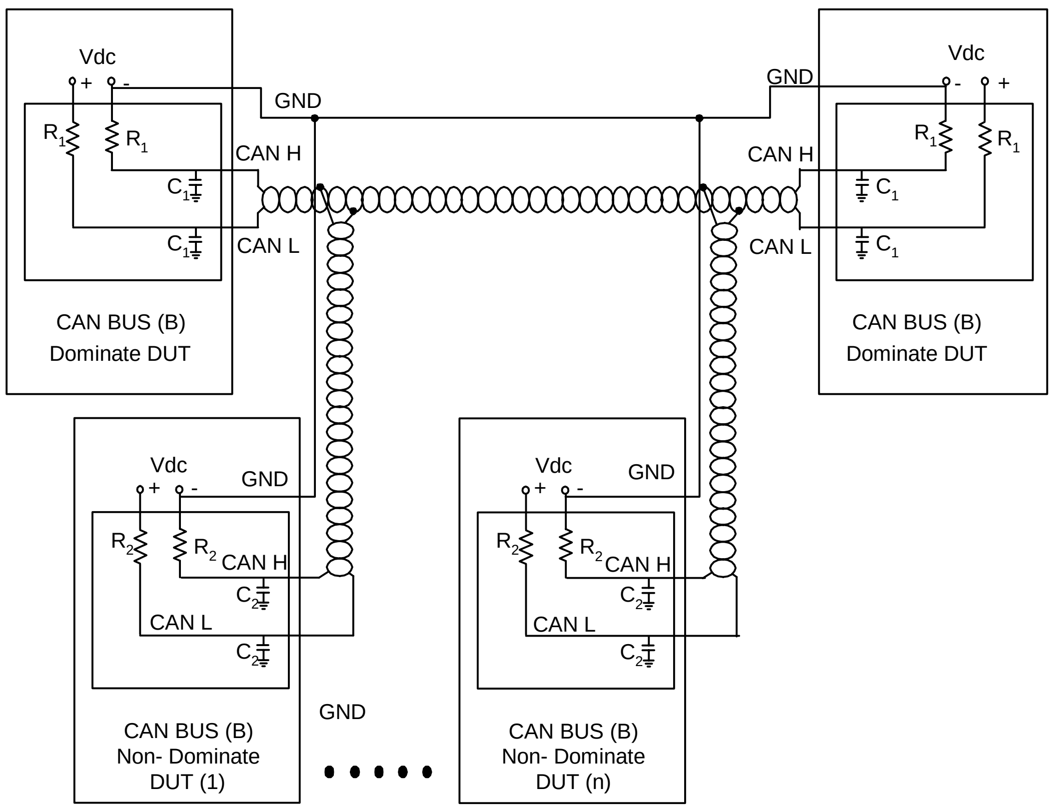

Figure D.1: CAN-B System DUT Interface Layout

Table D.1: CAN-B Bus Termination

Type of DUT	Internal Resistor	Internal Capacitor
Dominant node	R_1 = 560 ohms	C_1 = 100 pF (maximum allowed)
Non-dominant node	R_2 = 4.7 kohms	C_1 = 100 pF (maximum allowed)

Table D.2: CAN-B Bus Vdc

Test Mode	Vdc
Normal	5 Volt
Sleep	12 Volt

There are two dominant node modules in a vehicle.

D.3.2 CAN-B Termination Requirements Using Optical CAN Interface (OPTOCAN 2000)

The OPTOCAN 2000 CAN-B optical interface provides 6 resistor values (100/180/270/390/560/1000 ohms) with 470 pF capacitor for each line (CAN H and CAN L).

D.3.2.1 Vehicle Level EMC Testing

A) Test Dominant DUT

If the OPTOCAN 2000 is used to replace a dominant component in a vehicle, the resistance value R=560 ohms shall be selected. The resistor value R=560 ohms shall be selected for the transceiver that is connected to the computer through the CAN-B probe (OPTO 1041).

B) Test Non-Dominant DUT

If the OPTOCAN 2000 is used to replace a non-dominant component in a vehicle, the resistance value R=1.0 kohm (should be 4.7 kohms) shall be selected. The resistor value R=560 ohms shall be selected for the transceiver that is connected to the computer through the CAN-B probe (OPTO 1041).

C) CAN-B Communication Only

If the OPTOCAN 2000 is used for CAN BUS communication purpose only without removing any component from a vehicle, the resistance value R=1.0 kohm (should be 4.7 kohms) shall be selected. The resistor value R=560 ohms shall be selected for the transceiver that is connected to the computer through the CAN-B probe (OPTO 1041).

D.3.2.2 Component Level EMC Testing

The setup for normal operation is shown in Figure D.2.

A) Test Dominant DUT:

If the testing DUT is a dominant component, the resistance value R=560 ohms shall be selected. C=470 pF shall be added for CAN H and CAN L (refer to Figure D.2). The capacitors shall be located at the end of the harness close to the transceiver. Note: Total capacitor value is about 1,000 pF per line (470 pF is built in the transceiver). The resistor value R=560 ohms shall be selected for the transceiver that is connected to the computer through the CAN-B probe (OPTO 1041).

B) Test Non-Dominant DUT:

If the testing DUT is a non-dominant component in a vehicle, the resistance value R=270 ohms shall be selected. C=470 pF shall be added for CAN H and CAN L (refer to Figure D.2). The capacitors shall be located at the end of the harness close to the transceiver. Note: Total capacitor value is about 1,000 pF

(470 pF is built in the transceiver). The resistor value R=560 ohms shall be selected for the transceiver that is connected to the computer through the CAN-B probe (OPTO 1041).

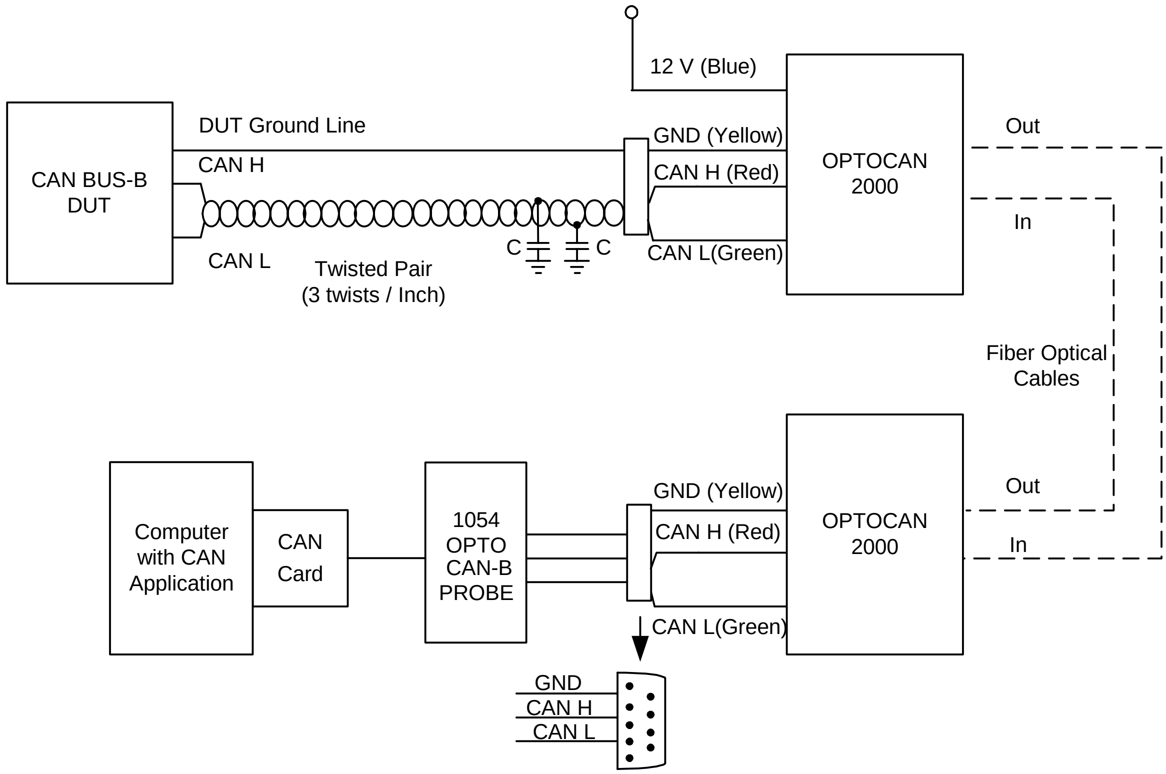

Figure D.2: CAN-B Interface Using OPTOCAN

D.4 CAN-C

D.4.1 Typical CAN BUS system – CAN-C (500 kbps) or CAN-IHS (125 kbps)

The Figure D.3 and Table D.3 show the basic layout and internal impedance values for CAN-C or CAN-IHS.

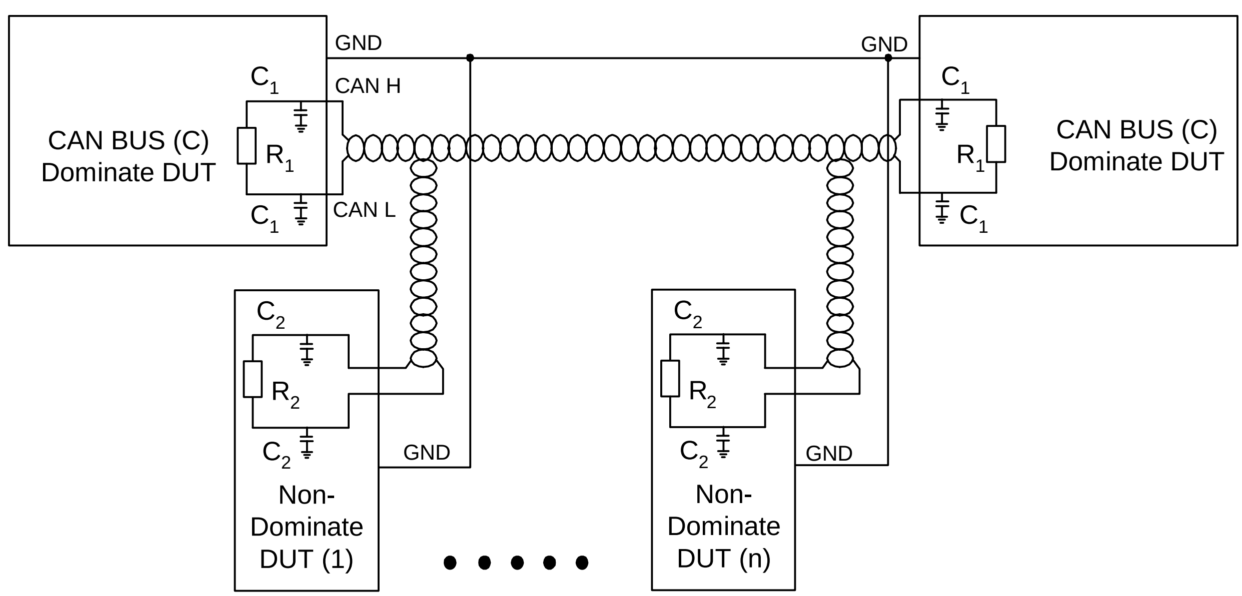

Figure D.3: CAN-C System DUT Interface Layout

Table D.3: CAN-C Bus Termination

Type of DUT	Internal Resistor	Internal Capacitor
Dominant node	R_1 = 120 ohms	C_1 = 47 pF (maximum allowed)
Non-dominant node	R_2 = 3.0 kohms	C_2 = 47 pF (maximum allowed)

There are two dominant modules in a vehicle.

D.4.2 CAN-C Termination Requirements Using Optical CAN Interface (OPTOCAN 2000)

The OPTOCAN 2000 CAN-C optical interface provides 3 resistor values (60 ohms, 120 ohms, or open) with 220 pF capacitors in each line (CAN H and CAN L).

D.4.2.1 Vehicle Level EMC Testing

A) Test Dominant DUT:

If the OPTOCAN 2000 is used to replace a dominant component in a vehicle, the resistance value R=120 ohms shall be selected. The resistor value R=120 ohms shall be selected for the transceiver that is connected to the computer through the CAN-C probe (OPTO 1041 or 251).

B) Test Non-Dominant DUT:

If the OPTOCAN 2000 is used to replace a non-dominant component in a vehicle, the resistance value R= open shall be selected. The resistor value R=120 ohms shall be selected for the transceiver that is connected to the computer through the CAN-C probe (OPTO 1041 or 251).

C) CAN-C Communication Only:

If the OPTOCAN 2000 is used for CAN BUS communication purpose only without removing any component from a vehicle, the resistance value R=open shall be selected. The resistor value R=120 ohms shall be selected for the transceiver that is connected to the computer through the CAN-C probe (OPTO 1041 or 251).

D.4.2.2 Component Level EMC Testing

The setup for normal operation is shown in Figure D.4.

A) Test Dominant DUT:

For the CAN-C, the resistance value R=120 ohms shall be selected. The total 220 pF shall be added for each line. If OPTOCAN 2000 is used, no additional capacitors are needed because there are 220 pF capacitances built in the transceiver. The resistor value R=120 ohms shall be selected for the transceiver that is connected to the computer through the CAN-C probe (OPTO 1041 or 251).

For CAN-IHS, the resistance value R=120 ohms shall be selected. The total 470 pF shall be added for each line. If OPTOCAN 2000 is used, C=220-250 pF shall be added at each lines. The resistor value R=120 ohms shall be selected for the transceiver that is connected to the computer through the CAN-C probe (OPTO 1041 or 251).

B) Test Non-Dominant DUT:

For the CAN-C, the resistance value R=60 ohms shall be selected. The total 220 pF shall be added for each line. If OPTOCAN 2000 is used, no additional capacitors are needed because there are 220 pF capacitances built in the transceiver. The resistor value R=120 ohms shall be selected for the transceiver that is connected to the computer through the CAN-C probe (OPTO 1041 or 251).

For CAN-IHS, the resistance value R=60 ohms shall be selected. The total 470 pF shall be added for each line. If OPTOCAN 2000 is used, C=220-250 pF shall be added at each lines. The resistor value R=120 ohms shall be selected for the transceiver that is connected to the computer through the CAN-C

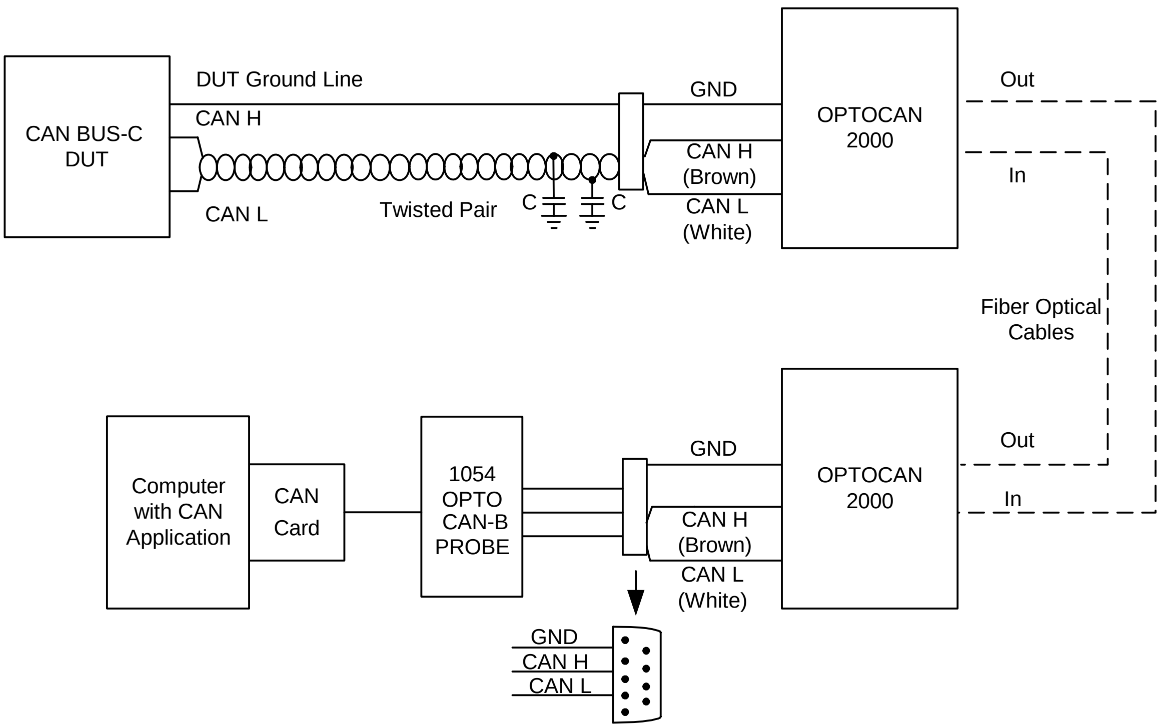

Figure D.4: CAN-C Interface Using OPTOCAN

D.5 CAN-B Termination Requirements without Using Optical CAN Interface

D.5.1 Vehicle Level EMC Testing

A) Dominant Component:

If a dominant component is removed in a vehicle, the resistance value R and R_{pullup}=560 ohms and C=100 pF shall be used to substitute for this component. See Figure D.5 for the setup.

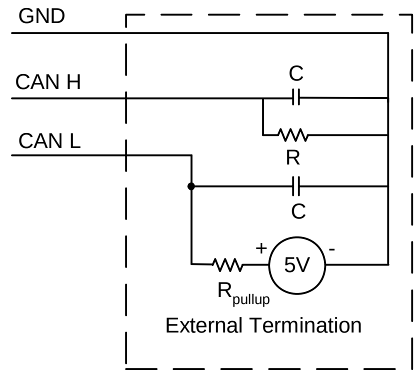

Figure D.5: CAN-B Termination Setup for Vehicle Level EMC Testing

B) Test Non-Dominant DUT:

If a non-dominant component is removed from a vehicle, no termination is required.

D.5.2 Component Level EMC Testing

The setup for normal operation is shown in Figure D.6.

A) Test Dominant DUT:

If the testing DUT is a dominant component, the resistance value R and R_{pullup}=560 ohms and C=1000 pF (considering the capacitance for total 10 modules) shall be used.

B) Test Non-Dominant DUT:

If the testing DUT is a non-dominant component, the resistance value R and R_{pullup}=270 ohms and 1000 pF (considering the capacitance for total 10 modules) shall be used.

The length from the CAN BUS harness to the CAN probe is less than 200 mm.

Note: if the chamber filters are in the lines of CAN-B, the capacitance of the filters shall be considered. For example, the Tusonix 4201-001 has 1000 pF. The filters are installed in the Chrysler ALSE and TEM. No additional capacitances are required for the testing at the Chrysler ALSE and TEM.

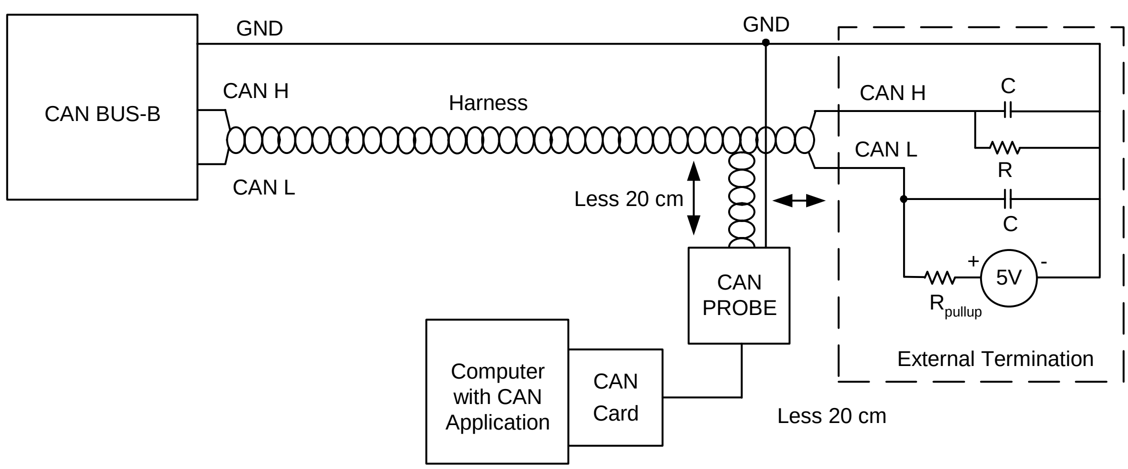

Figure D.6: CAN-B Termination Layout for Sleep Mode

D.5.2.1 Sleep Mode

For sleep mode, the equivalent external bus load is shown in Figure D.6. The R is the same value as normal mode. During sleep, the bus voltage on CAN_L is close to battery voltage (12 V, not 5 V).

D.6 CAN-C Termination Requirements without Using Optical CAN Interface

D.6.1 Vehicle Level EMC Testing

A) Dominant Component:

If a dominant component is removed in a vehicle, the resistance value R=120 ohms shall be used to substitute for this component. See Figure D.7 for the setup.

B) Test Non-Dominant DUT:

If a non-dominant component is removed in a vehicle, the resistance value R =3.0 kohms and C=47 pF shall be used to substitute for this component. See Figure D.8 for the setup.

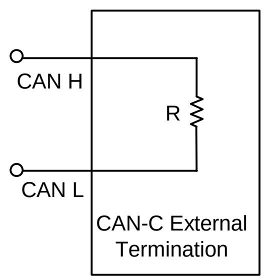

Figure D.7: CAN-C Termination Setup for Vehicle Level EMC Testing

D.6.2 Component Level EMC Testing

The setup is shown in Figure D.8.

A) Test Dominant DUT:

For CAN-C, if the testing DUT is a dominant component, the resistance value R=120 ohms and C=220-250 pF shall be used.

For CAN-IHS, if the testing DUT is a dominant component, the resistance value R=120 ohms and C=470 pF shall be used.

B) Test Non-Dominant DUT:

For CAN-C, if the testing DUT is a non-dominant component, the resistance value R=60 ohms and C=220-250 pF shall be used.

For CAN-IHS, if the testing DUT is a dominant component, the resistance value R=60 ohms and C=470 pF shall be used.

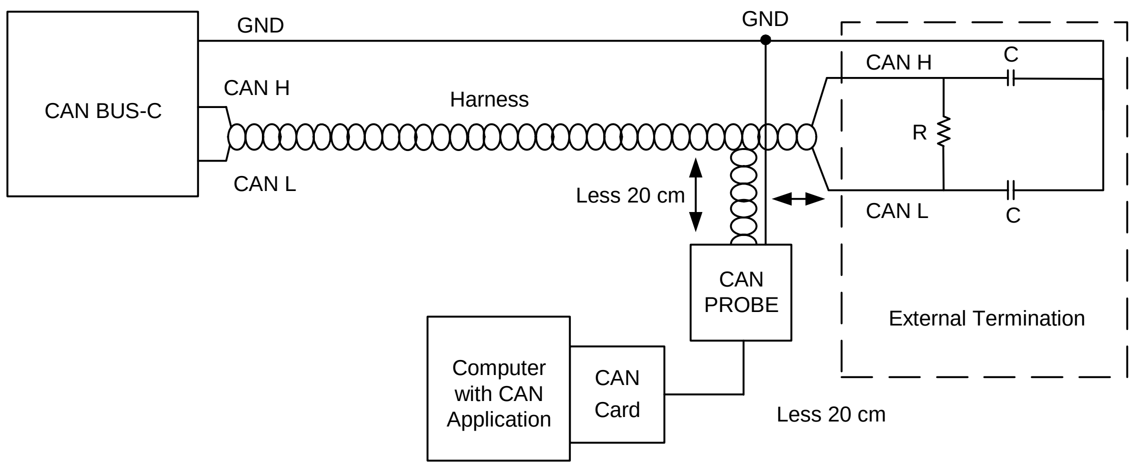

Figure D.8: CAN-C Termination Layout

Notes:

1) Since the Tusonix 4201-001 filter has 1000 pF. The CAN-C will not work due to the loading of the capacitance. The CAN Optical Interface shall be used to perform the testing at the Chrysler ALSE and TEM.
2) Most CAN DUTs will go to network sleep and stop transmitting messages when alone on the bus. A CAN tool or another CAN DUT has to be present on the bus during the test to keep the DUT alive.

D.7 LIN Bus Termination Requirements

If using a commercial probe, check manufacturer specifications for the built in termination information. For example, Vector LINcab probe (6259 opto) provides the terminations discussed in the following sections based on the configurations of the software set for Master or Slave termination.

D.7.1 LIN Bus internal termination

A) The component has the master function, the capacitance is 1 nF and the resistance is 1 kohm.

B) The component has the slave function, the capacitance is 220 pF and resistance is 100 kohms.

D.7.2 LIN Termination Requirements without Using Optical CAN Interface

D.7.2.1 Vehicle Level EMC Testing

A) Master Component:

If a master component is removed in a vehicle, the resistance value R=1 kohm and C=1 nF shall be used to substitute for this component. See Figure D.9 for the setup.

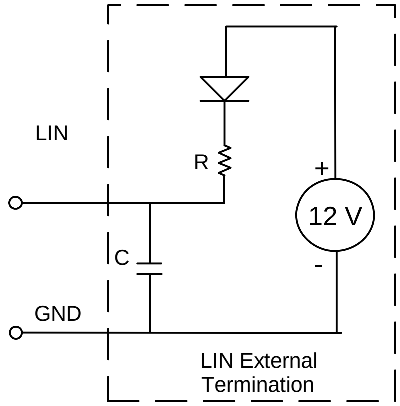

Figure D.9: LIN Termination Setup for Vehicle Level EMC Testing

B) Slave Component:

No termination is required for the slave component.

D.7.2.2 Component Level EMC Testing

The setup is shown in Figure D.9.

A) Test Master DUT:

If the testing DUT is a master component, the resistance value R=10 kohms and C=3.3 nF shall be used.

B) Test Slave DUT:

If the testing DUT is a slave component, the resistance value R= 1 kohm and C=3.3 nF shall be used.

Note: Vector LINcab probe (6259 opto) has the terminations built into the probe. No additional termination is required.

End of Annex D
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Annex E (informative)

Additional Information

E.1 Relationship to Other Standards

This standard is a part of a series of standards intended to assure electromagnetic compatibility in vehicle electrical and electronic systems. During the module design process, reference should be made to DaimlerChrysler CG design standards DS-150 and DS-151 for information on PC board layout and the SAE J1752 or IEC 61967 series of standards for techniques to evaluate the RF emissions potential of integrated circuits. See references in DC-11224.

E.2 Component Location in the Vehicle

Emissions

For most module locations in a metallic vehicle, the vehicle body provides some shielding. However, the risk of interference increases for modules in exposed or unshielded locations that have enhanced visibility to the vehicle antenna(s). For front mounted vehicle antennas, these exposed locations are the high instrument panel area (instrument cluster) and the overhead console. For vehicles with rear-mounted antennas or nonmetallic body panels, other locations may have enhanced visibility to the vehicle antenna(s).

Immunity

A wide range of factors including location, wiring interconnects and the shielding effectiveness of the vehicle affects the actual EMC performance of a system as installed in a vehicle. Some level of shielding may be provided by the vehicle body. Instrument clusters and overhead consoles are in locations where shielding effectiveness cannot be assumed and therefore they may be at increased risk of RF exposure. Other modules in exposed or unshielded locations, or any electronics in a nonmetallic vehicle, may also require special considerations in order to maintain the required vehicle immunity levels in DC-11223. This should be considered in the product specification and EMC test plan.

E.3 Pin Conducted RF Emissions (PCE)

This test evaluates the radiated RF emissions potential that the DUT will present when installed in a vehicle. A measurement of open circuit or simulated open circuit RF voltage, referenced to ground, is made at all DUT input and output terminals, including unused connector pins. This test evaluates the RF characteristics of a printed circuit board (PCB), including the ground plane and bypassing effectiveness. It is at the prototype PCB level where the diagnostic capabilities of this test facilitate cost-effective improvements in the RF emissions performance of the component.

E.4 DRFI

The Direct RF Power Injection (DRFI) test in Annex B, a pin-by-pin test, is particularly effective when used as part of the engineering development of the electronic component as it provides circuit board level diagnostic information to facilitate corrective action.

E.5 RF Immunity of RF Link Systems

Vehicle systems that use a low power RF link (i.e., RF remote keyless entry), require a low RF environment near their operating frequency to realize their normal operating range. In the presence of RF sources within this "window of vulnerability", devices such as RF RKE will exhibit reduced range or inhibited remote operation. This immunity window can be reduced by improved filtering in the receive module and should not exceed ± 5% of the system operating frequency. The product specification should define the acceptable performance limits for the system in the vicinity of its operating frequency range and the EMC test plan should take this into account.

E.6 RF Emissions of RF Link Systems

RF link systems will necessarily have emissions at their operating frequency and these emissions may exceed the emission limits specified for that band. Typically, these emission requirements are to control the emissions from unintended radiators in order to protect the operation of RF link devices and are not intended to inhibit the range or operation of these RF link systems themselves. The EMC test plan should take this into account.

End of Annex E

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Annex F (informative)

Broadband Artificial Network (BAN) Design Requirements

NOTE: DaimlerChrysler holds patents (#4,763,062 and #5,541,521) on an RF isolator or BAN design. This BAN is commercially available. Other designs may be used if they meet the design intent.

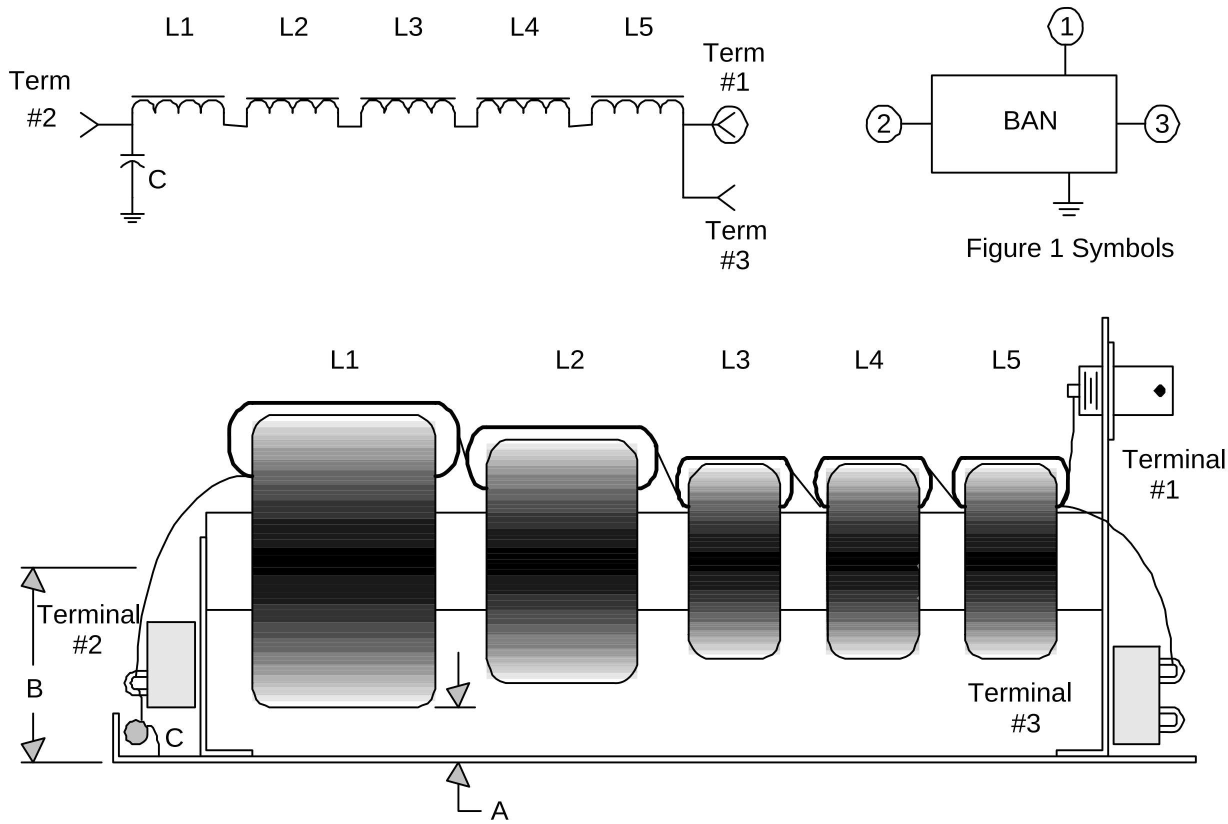

Figure F.1: Example Schematic and Assembly Drawing of a BAN (Side View)

The BAN is assembled from the appropriate wound toroid cores listed in Tables F.3 through F.7 on a nonconductive and nonmagnetic rod supported over a copper ground plane. In order for this isolator to function as designed up to 400 MHz, care must be taken to minimize and control parasitic capacitance, especially on the DUT (terminal #1) end of the BAN. To this end, the ground plane shall not extend out past L5 farther than necessary and any conductive support structure on the DUT end of the BAN shall be minimized.

- A is the separation between the L1 core and the ground plane surface.
- B is the distance from the axis of the cores to the ground plane surface and is the minimum separation between adjacent L1 of additional BAN when assembled into a multi line unit.
- Terminal #1: RF input, low capacitance BNC or similar RF connector, for CAN BAN, this BNC shall be 30 mm min above the ground plane
- Terminal #2: Connection to the DUT supply and/or load support circuitry
- Terminal #3: Connection to the DUT input or output lead

  Note: Terminal #1 and #3 are connected together in the BAN.

BAN bypassing - The supply/load/support circuitry end of the BAN shall be bypassed to ground. This requires the optimum value of capacitor to provide sufficiently low impedance across the frequency range of interest for the test. Minimum lead length is to be used. Suggested optimum bypass capacitor C is a 0.047 uF ceramic monolithic capacitor for normal BANs, 0.01 uF for high speed BANs and 470 pF for CAN BANs.

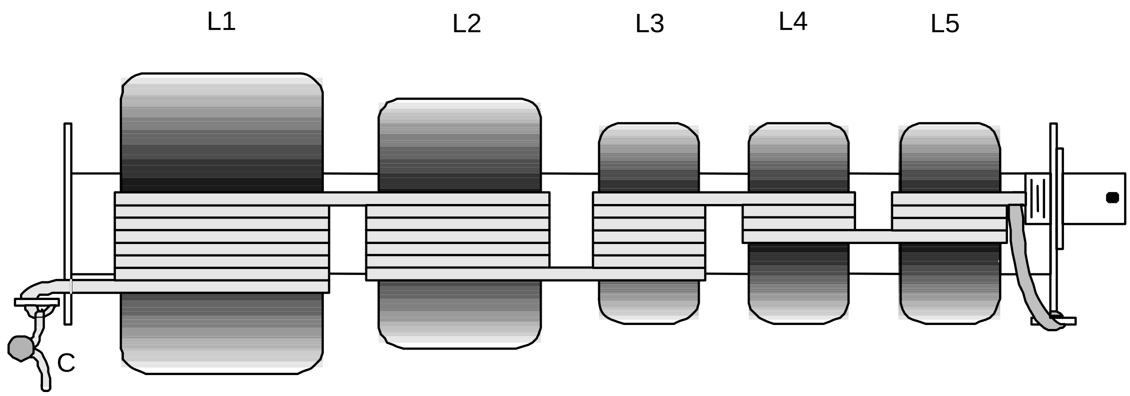

Figure F.2: Typical Wiring Arrangement (Top View)

BAN winding - The recommended technique for winding the assembly utilizes one continuous piece of wire. Leave sufficient wire for the termination on the capacitor end of L1 and wind the turns close-spaced on the toroid for L1. At this point, hold the toroid for L2 approximately 6 mm from L1 and wind the turns for L2 close-spaced in the opposite direction so that the windings are parallel to those of L1. Continue in this manner with L3 through L5 with the windings zigzagging from L1 to L5. Figure F.2 shows this arrangement. The remaining wire should be cut off allowing enough to connect L5 to its terminal lug. Install the assembly on the dowel, and then assemble the dowel to the support lugs (with the close-spaced windings away from the ground plane) with nonmetallic screws. Use minimum lead length for all connections. It is very important to control the geometry of the BAN assembly to minimize the parasitic capacitance at the terminal #1 end of the BAN, as this is critical to meeting the impedance requirements specified in Tables F.1 and F.2. Through loss is measured from terminals 1 and 3 to terminal 2.

Table F.1: Impedance and Through Loss Requirements - BANs up to 8 A Capacity

Frequency Range [MHz]	Min. Impedance [ohms]			Min. Through Loss [dB]		
	Standard	High Speed	CAN	Standard	High Speed	CAN
1 to 20	500	N/A	500	35	N/A	20
20 to 250	500	500	200	35	35	20
250 to 400	200	200	N/A	35	35	N/A

Table F.2: Impedance and Through Loss Requirements - BANs Over 8 A Capacity

Frequency Range [MHz]	Min. Impedance [ohms]	Min. Through Loss [dB]
1 to 2	200	20
2 to 150	400	20
150 to 400	100	20

Current Capacity - Current handling capacity shall be included in the parameters of the BAN design. The saturation characteristics of ferrite or powdered iron cores are a significant factor in the current handling capacity of a BAN.

Table F.3: Coil Winding Information – 0.5 A BAN

Coil	Core Type	Number of Turns	Inductance [μH]
L1	FT82-77	12	180
L2	FT50-61	4	1
L3	FT50-67	4	0.6
L4	FT50-68	4	0.2
L5	FT50-68	4	0.2

A = 4 mm, B is equal to or greater than 15 mm.
Wire is approximately 0.40 mm diameter (#26 AWG or #26 B&S) and approximately 1 m in length.
Core material - Ferrite (Amidon part numbers shown, equivalent parts are acceptable).
Inductance is measured at 10 kHz for L1, calculated for L2-L5.

Table F.4: Coil Winding Information – 0.5 A High Speed BAN

Coil	Core Type	Number of Turns	Inductance [μH]
L2	FT50-61	4	1
L3	FT50-67	4	0.6
L4	FT50-68	4	0.2
L5	FT50-68	4	0.2

A = 4 mm, B is equal to or greater than 15 mm. Inductance is calculated for L2-L5.
Wire is approximately 0.40 mm diameter (#26 AWG or #26 B&S). Bypass capacitor is 0.01 μF.
Core material - Ferrite (Amidon part numbers shown, equivalent parts are acceptable).

NOTE: The high data rate BAN is available for testing high-speed, single line, signal or bus lines. To fabricate a high data rate BAN, remove L1 (the 12-turn toroid) from a 0.5 A isolator and replace the 0.047 μF bypass capacitor with 0.01 μF. This lowers the inductance of the isolator to approximately 2 μH and raises the resonant frequency allowing 125 k baud data transmission bandwidth. When this isolator is required, the frequency range for Direct RF Injection is modified to 20 MHz to 400 MHz. Check with the E/E Systems Compatibility Department of DaimlerChrysler Corporation Scientific Laboratories for additional details.

NOTE: The CAN BAN has been developed for immunity and emissions testing of CAN bus lines. It is constructed with two lines bifilar wound (ten turns per inch) on six cores with two bypass caps on each line (terminal #2) and two capacitor feeds from the two lines to a common BNC connector (terminal #1) for common mode testing. Check with the E/E Systems Compatibility Department of DaimlerChrysler Corporation Scientific Laboratories for additional details and current information as this design is evolving.

Table F.5: Coil Winding Information – 0.5 A CAN BAN

Coil	Core Type	Number of Turns (2 lines - bifilar wound, 4 turns/cm or 10 turns/in)
L1	FT82-77	12
L2	FT50-61	4
L3	FT50-67	4
L4	FT50-68	7
L5	FT50-68	5
L6	FT50-68	5

A = 4 mm, B is equal to or greater than 15 mm. BNC connector is Amphenol 31-10 minimum 30 mm above the ground plane. Wire is approximately 0.40 mm diameter (#26 AWG or #26 B&S) and approximately 1 m in length.
Core material - Ferrite (Amidon part numbers shown, equivalent parts are acceptable).
1) For PCE and DRFI tests, the bypass capacitor is 470 pF, split feed capacitors are 470 pF. This BAN with the split feed capacitor is called Common Mode CAN BAN with Single Point Injection.
2) For BCI and TEM Immunity Tests, the split feed capacitors shall be removed. The bypass capacitors shall be changed to 1500 pF. This BAN without the split feed capacitor is called Common Mode CAN BAN without Single Point Injection. The tolerance on the capacitors is ± 2%.

Table F.6: Coil Winding Information - 2 A BAN

Coil	Core Type	Number of Turns	Inductance [μH]
L1	FT114A-77	8	180
L2	FT82-43	6	20
L3	FT50-67	6	1
L4	FT50-68	4	0.2
L5	FT50-68	4	0.2

A = 7 mm, B is equal to or greater than 17 mm
Wire is approximately 0.64 mm diameter (#22 AWG or #22 B&S) and approximately 1.3 m long.
Core material - Ferrite (Amidon part numbers shown, equivalent parts are acceptable).
Inductance is measured at 10 kHz for L1 and L2, calculated for L3-L5.

Table F.7: Coil Winding Information - 30 A BAN

Coil	Core Type	Number of Turns	Inductance [μH]
L1	T184-26	15	38
L2	T157-26	12	15
L3	T130-26	5	2.4

A = 12 mm, B is equal to or greater than 30 mm, Inductance is measured at 10 kHz
Wire is approximately 1.61 mm diameter (#14 AWG or #14 B&S) and approximately 1.5 m long.
Core material - Powdered Iron (Amidon part numbers shown, equivalent parts are acceptable).

End of Annex F

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Annex G (informative)

ALSE Characterization and Verification

G.1 Initial Chamber Characterization

The procedure is only required when the chamber RF System is initially setup, or when the system verification is performed. The following procedure is a guideline for chamber characterization.

RF Path Characterization: Measure all cable losses, amplifier & antenna gain and directional coupler attenuation. Ensure that the RF power does not overdrive the RF equipment, i.e., antenna, directional coupler.

Antenna Location Optimization: The distance between the probe and any antenna is a minimum of one (1) meter. Typically if the antenna is placed further away from the test region, it provides a better uniformity pattern. To optimize the antenna position, the limitation of amplifier power shall be considered.

RF Uniformity Measurement: Define a 0.5x1.0 meter rectangle area on the Vertical Plane (Figure G.1). The uniformity calculations are based on each point (e.g. a1, b1, c1) which is perpendicular to the active antenna. The reference point is point c3. The uniformity shall be calculated by 20*log(any position / c3) in dB. The measured uniformity shall be less or equal to 6 dB when referenced to point c3. There is no requirement for the two top corner areas. If the separation distances are used between the DUT table and antenna with defined antenna, the uniformity results shall satisfy the requirement.

Field Strength Level Calibrations with a CW Signal: The RF probe shall be placed on the DUT turntable at an isotropic angle such that no axis of the probe aligns directly with the polarization of the radiated electric field. The calibration frequencies are the frequency points defined in the requirements of LP-388C-65.

The chamber uniformity and characterization results shall be documented and dated.

G.2 Routine Chamber Verification

This procedure shall be performed every six months.

Amplifier gain verification: To ensure the gain of the amplifiers meets the minimum requirements to achieve the desired RF field strength levels.

RF calibration verification: The verification is based on the test sweep method (evaluation mode) with a field probe re-located at the calibration reference. The field strength levels shall be compared between the computer calibration table values and the field probe. The differences shall be within 10% of each other. Repeat the procedure for all bands and field levels. The results shall be recorded along with the calibration date.

RF calibration correction: Any suspicious results from the band verification shall be corrected by investigating the system setup and replacing hardware components if required. The band RF characterization shall be performed based on the above procedure.

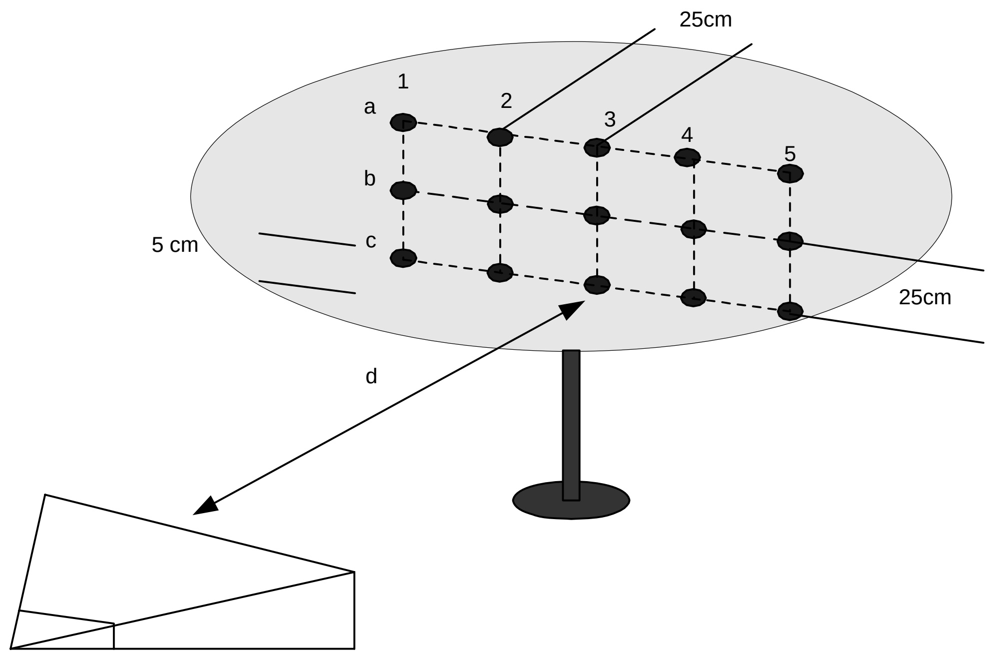

Figure G.1: Uniformity Measurement Dimension

End of Annex G

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Annex H (informative)

TEM Cell Characterization and Verification

H.1 System Characterization

The TEM cell system characterization is based on theoretical calculations. Use equation (1) to calculate the test field strength resulting from a specific Forward Power

$$E_{TEM} = \frac{\sqrt{Z_o P_{in}}}{h} \quad (1)$$

Where P_{in} is the Forward Power in watts; E_{TEM} is the RF Field Strength in Volts/meter; h is the TEM cell septum height in meters; Z_0 is the characteristic impedance at the test frequency measured at the input of the TEM cell. To get an accurate measured value of P_F, the coupling factor of the dual directional coupler and the system cable losses (both as a function of frequency) shall be measured and applied to calculate the actual P_F.

H.2 Test Signal Quality and Level Verification

This test shall be performed every six months.

H.3 Test signal quality verification

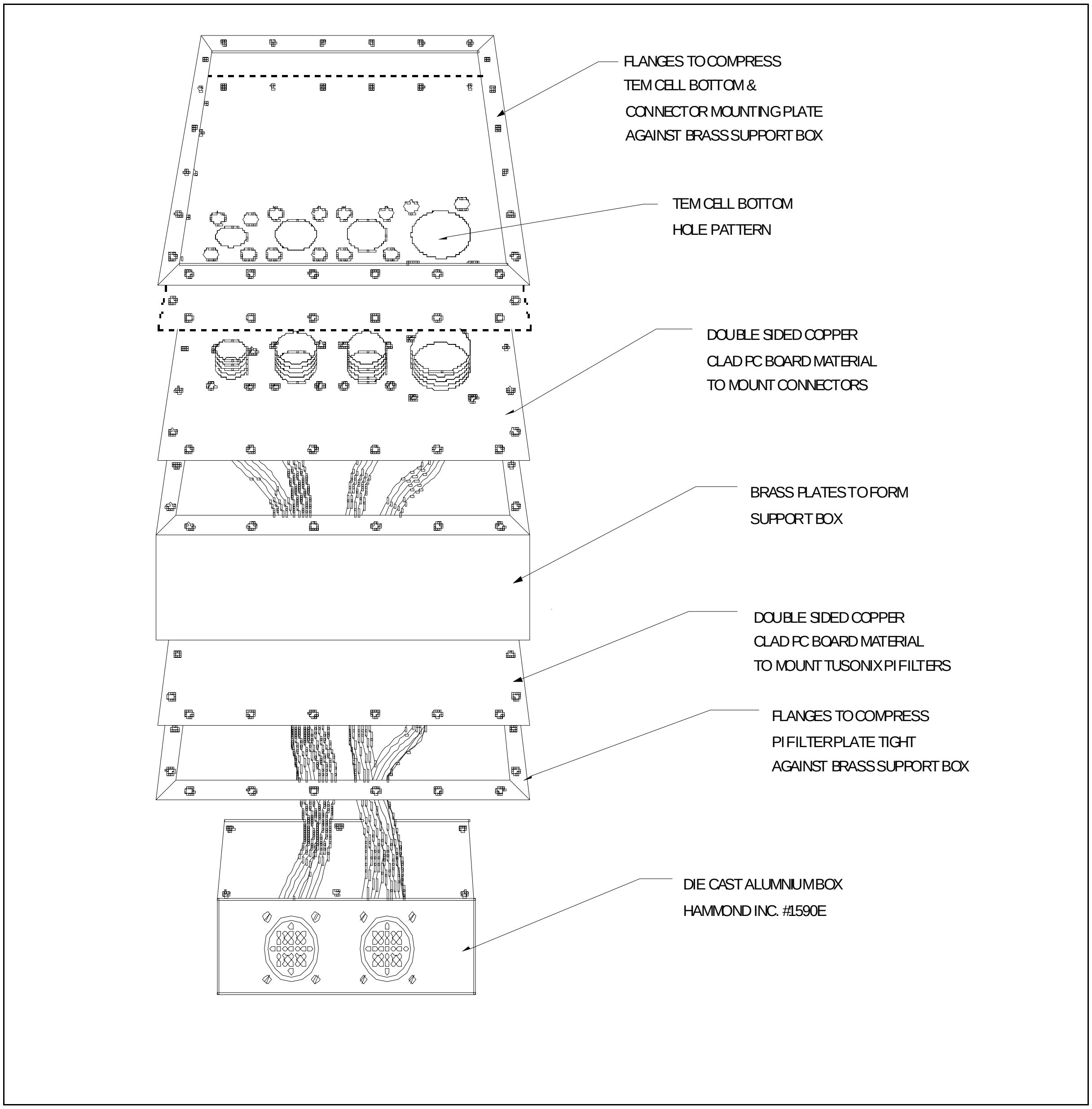
Compare the amplitudes of the harmonics of the test signals at the amplifier output. The power level shall be set to generate the highest field strength level required for testing. Use a spectrum analyzer to measure the amplitudes of the harmonics as the test frequency is swept across the test frequency range. The second harmonic shall be at least 12 dB lower than the fundamental signal.

H.4 Test signal amplitude verification

Place a calibrated field strength probe into the empty TEM cell and compare the measured field strength to the calculated field strength over the frequency range of the test. The field probe reading shall be within 15 percent of the calculated field strength. If the 15 % requirement is exceeded, the test stand shall be analyzed to determine the cause. The results shall be recorded along with the verification date.

H.5 Filtered Bulkhead Panel Design

To set the RF boundary for the TEM cell and allow the test load box to be located at out side of the cell, the RF filters shall be used. Figure H.2 provides an example of the filter assembly and the filter type information.



Note: For illustration purposes, output shown has two connectors. The filter: Tusonix 4201-001 or equivalent.

Figure H.1: Filtered Bulkhead Panel Design – Overall Layout

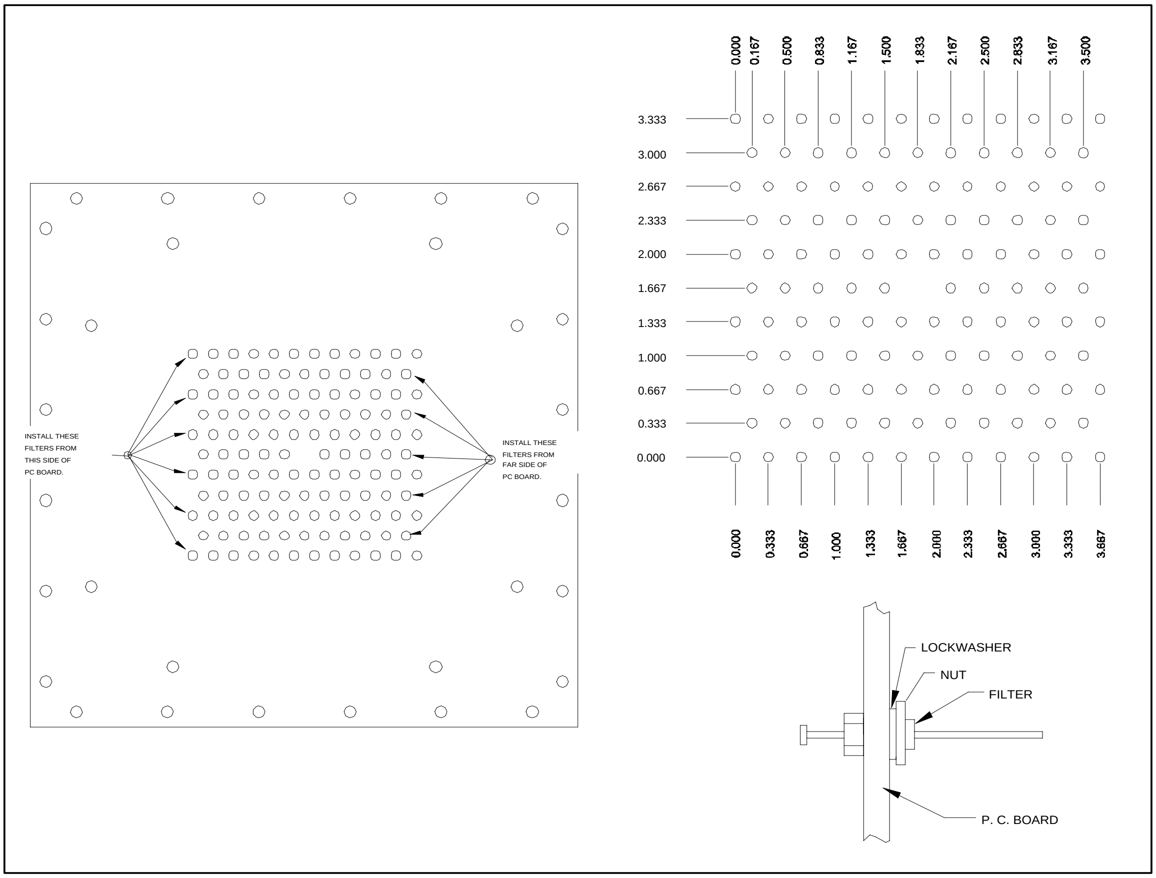


Figure H.2: Filtered Bulkhead Panel Design – Feedthrough Capacitors

H.6 Test Set-Up

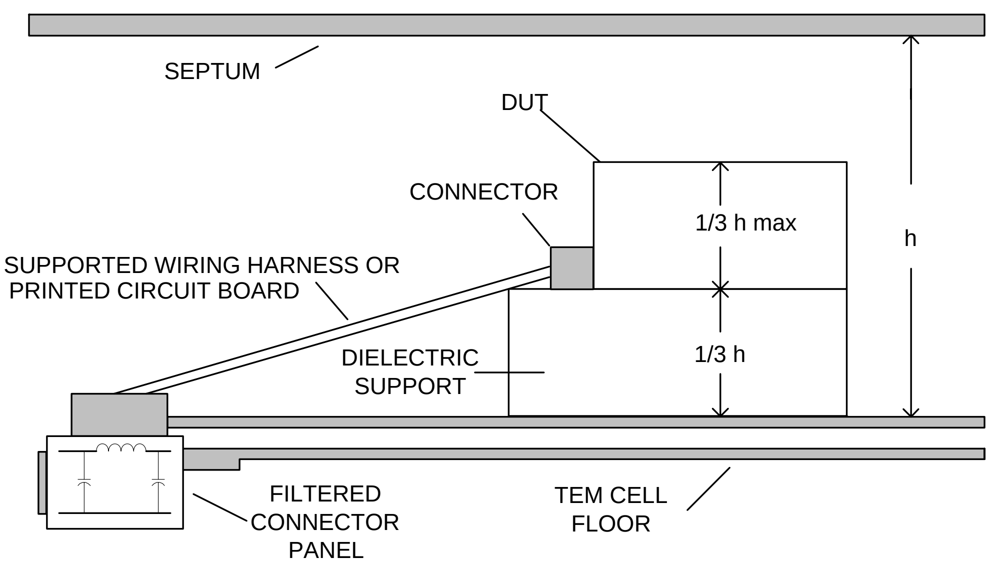


Figure H.3: Standard DUT and Harness Setup

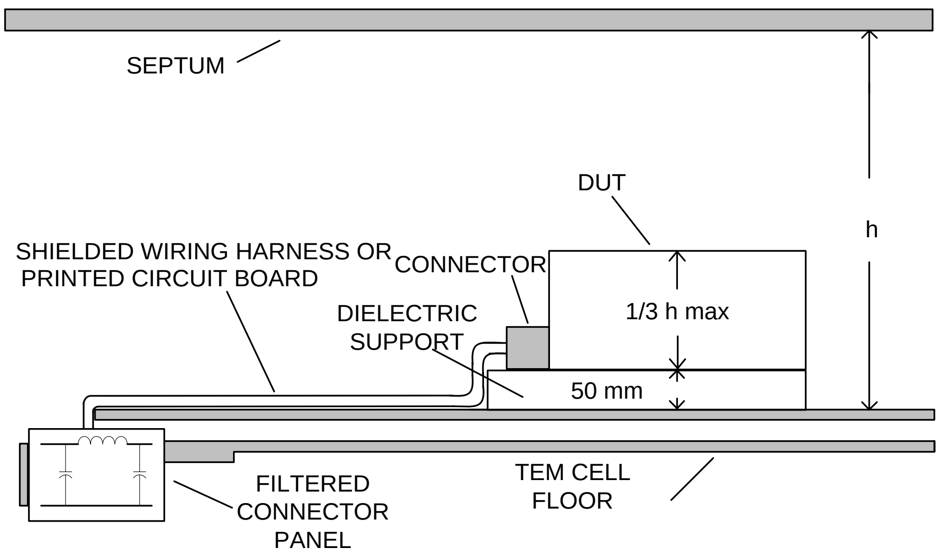


Figure H.4: Special DUT and Harness Setup to Minimize Harness Coupling

End of Annex H

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Annex I (informative)

Frequency Tables for Immunity Testing Using Percentage Steps

Table I-1 represents the implementation of the percentage increments given in DC-11224, RF Immunity Test Frequency Resolution Table.

Table I-1: RF Immunity Percentage Progression Frequency Test Table (MHz)

1 to 10 MHz 4.0%			**10 to 100 MHz 2.0%**					
100 to 1,000 MHz 1.0%		**1 000 to 3 200 MHz 0.5%**						
1.00	12.94	53.83	150.38	307.83	630.16	1138.46	1630.32	2334.70
1.04	13.19	54.91	151.88	310.91	636.47	1144.15	1638.48	2346.37
1.08	13.46	56.00	153.40	314.02	642.83	1149.87	1646.67	2358.10
1.12	13.73	57.12	154.93	317.16	649.26	1155.62	1654.90	2369.89
1.17	14.00	58.27	156.48	320.33	655.75	1161.40	1663.18	2381.74
1.22	14.28	59.43	158.05	323.54	662.31	1167.21	1671.49	2393.65
1.27	14.57	60.62	159.63	326.77	668.93	1173.04	1679.85	2405.62
1.32	14.86	61.83	161.22	330.04	675.62	1178.91	1688.25	2417.65
1.37	15.16	63.07	162.83	333.34	682.38	1184.80	1696.69	2429.74
1.42	15.46	64.33	164.46	336.67	689.20	1190.73	1705.17	2441.88
1.48	15.77	65.62	166.11	340.04	696.09	1196.68	1713.70	2454.09
1.54	16.08	66.93	167.77	343.44	703.05	1202.66	1722.27	2466.36
1.60	16.41	68.27	169.45	346.87	710.09	1208.68	1730.88	2478.70
1.67	16.73	69.63	171.14	350.34	717.19	1214.72	1739.53	2491.09
1.73	17.07	71.03	172.85	353.85	724.36	1220.79	1748.23	2503.54
1.80	17.41	72.45	174.58	357.38	731.60	1226.90	1756.97	2516.06
1.87	17.76	73.90	176.33	360.96	738.92	1233.03	1765.76	2528.64
1.95	18.11	75.37	178.09	364.57	746.31	1239.20	1774.59	2541.29
2.03	18.48	76.88	179.87	368.21	753.77	1245.39	1783.46	2553.99
2.11	18.85	78.42	181.67	371.90	761.31	1251.62	1792.38	2566.76
2.19	19.22	79.99	183.49	375.61	768.92	1257.88	1801.34	2579.60
2.28	19.61	81.59	185.32	379.37	776.61	1264.17	1810.35	2592.49
2.37	20.00	83.22	187.17	383.16	784.38	1270.49	1819.40	2605.46
2.46	20.40	84.88	189.05	387.00	792.22	1276.84	1828.49	2618.48
2.56	20.81	86.58	190.94	390.87	800.14	1283.23	1837.64	2631.58
2.67	21.22	88.31	192.85	394.77	808.14	1289.64	1846.82	2644.73
2.77	21.65	90.08	194.77	398.72	816.22	1296.09	1856.06	2657.96
2.88	22.08	91.88	196.72	402.71	824.39	1302.57	1865.34	2671.25
3.00	22.52	93.72	198.69	406.74	832.63	1309.08	1874.67	2684.60
3.12	22.97	95.59	200.68	410.80	840.96	1315.63	1884.04	2698.03
3.24	23.43	97.50	202.68	414.91	849.37	1322.21	1893.46	2711.52
3.37	23.90	100.00	204.71	419.06	857.86	1328.82	1902.93	2725.07
3.51	24.38	101.00	206.76	423.25	866.44	1335.46	1912.44	2738.70
3.65	24.87	102.01	208.82	427.48	875.10	1342.14	1922.00	2752.39
3.79	25.36	103.03	210.91	431.76	883.85	1348.85	1931.61	2766.16
3.95	25.87	104.06	213.02	436.08	892.69	1355.59	1941.27	2779.99
4.10	26.39	105.10	215.15	440.44	901.62	1362.37	1950.98	2793.89
4.27	26.92	106.15	217.30	444.84	910.64	1369.18	1960.73	2807.86
4.44	27.45	107.21	219.48	449.29	919.74	1376.03	1970.54	2821.89
4.62	28.00	108.29	221.67	453.78	928.94	1382.91	1980.39	2836.00
4.80	28.56	109.37	223.89	458.32	938.23	1389.82	1990.29	2850.18
4.99	29.13	110.46	226.13	462.90	947.61	1396.77	2000.24	2864.44
5.19	29.72	111.57	228.39	467.53	957.09	1403.76	2010.24	2878.76
5.40	30.31	112.68	230.67	472.21	966.66	1410.78	2020.29	2893.15
5.62	30.92	113.81	232.98	476.93	976.33	1417.83	2030.40	2907.62
5.84	31.54	114.95	235.31	481.70	986.09	1424.92	2040.55	2922.16

1 to 10 MHz	**4.0%**		**10 to 100 MHz**	**2.0%**				
100 to 1,000 MHz	**1.0%**	**1 000 to 3 200 MHz**		**0.5%**				
6.07	32.17	116.10	237.66	486.52	1000.00	1432.04	2050.75	2936.77
6.32	32.81	117.26	240.04	491.38	1005.00	1439.20	2061.00	2951.45
6.57	33.47	118.43	242.44	496.30	1010.03	1446.40	2071.31	2966.21
6.83	34.14	119.61	244.86	501.26	1015.08	1453.63	2081.67	2981.04
7.11	34.82	120.81	247.31	506.27	1020.15	1460.90	2092.07	2995.94
7.39	35.51	122.02	249.79	511.33	1025.25	1468.21	2102.53	3010.92
7.69	36.23	123.24	252.28	516.45	1030.38	1475.55	2113.05	3025.98
7.99	36.95	124.47	254.81	521.61	1035.53	1482.92	2123.61	3041.11
8.31	37.69	125.72	257.35	526.83	1040.71	1490.34	2134.23	3056.31
8.65	38.44	126.97	259.93	532.10	1045.91	1497.79	2144.90	3071.59
8.99	39.21	128.24	262.53	537.42	1051.14	1505.28	2155.63	3086.95
9.35	40.00	129.53	265.15	542.79	1056.40	1512.81	2166.40	3102.39
9.73	40.80	130.82	267.80	548.22	1061.68	1520.37	2177.24	3117.90
10.00	41.61	132.13	270.48	553.70	1066.99	1527.97	2188.12	3133.49
10.20	42.44	133.45	273.19	559.24	1072.32	1535.61	2199.06	3149.16
10.40	43.29	134.78	275.92	564.83	1077.68	1543.29	2210.06	3164.90
10.61	44.16	136.13	278.68	570.48	1083.07	1551.01	2221.11	3180.73
10.82	45.04	137.49	281.46	576.18	1088.49	1558.76	2232.21	3196.63
11.04	45.94	138.87	284.28	581.95	1093.93	1566.55	2243.38	3200.00
11.26	46.86	140.26	287.12	587.77	1099.40	1574.39	2254.59	
11.49	47.80	141.66	289.99	593.64	1104.90	1582.26	2265.87	
11.72	48.75	143.08	292.89	599.58	1110.42	1590.17	2277.19	
11.95	49.73	144.51	295.82	605.58	1115.97	1598.12	2288.58	
12.19	50.72	145.95	298.78	611.63	1121.55	1606.11	2300.02	
12.43	51.74	147.41	301.77	617.75	1127.16	1614.14	2311.52	
12.68	52.77	148.89	304.79	623.93	1132.80	1622.21	2323.08	
Total Number of Freq.	**641**							

Table I-2 represents the implementation of the required 10 frequency steps per decade as given in DC-11224, Magnetic Field Immunity.

Table I-2: Magnetic Field Immunity Percentage Progression Frequency Test Table (Hz)

15 to 30 000 Hz 10 freq/dec							
15	42	119	336	946	2667	7518	21188
17	47	134	377	1062	2993	8435	23773
19	53	150	423	1191	3358	9464	26674
21	60	168	474	1337	3768	10619	30000
24	67	189	532	1500	4228	11915	
27	75	212	597	1683	4743	13369	
30	84	238	670	1888	5322	15000	
34	95	267	752	2119	5972	16830	
38	106	299	844	2377	6700	18884	
Total Number of Freq.		**67**					