SOLAR ORBITER ENERGETIC PARTICLE DETECTOR

EPTHET-1 FM and EPTHET-2 PFM

EMC Test Plan and Procedure

Document ID: SO-EPD-KIE-TP-0037
Issue: 1
Revision: 0
Date: 28/02/2016

Signature not needed if electronically approved by route

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File: SO-EPD-KIE-TP-0037_iss1_rev0_EPTHET-1FM_EPTHET-2PFM-EMC-Test-Procedure.doc **Pages:** 55

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CHANGES RECORD

Issue	Revision	Date	Modified by	Section / Paragraph modified	Change implemented
1	0	28/02/2016		All	Initial release

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1 INTRODUCTION

1.1 Purpose

The aim of this document is to define the EPTHET-1 FM and EPTHET-2 PFM EMC (ElectroMagnetic Compatibility), tests plan and procedure. These tests will be performed to verify the EPTHET1&2 electronics design characteristics. The tests indicated in Table 1-1 are planned to be performed on EPTHET-1 FM and EPTHET-2 PFM.

Table 1-1. Planned tests for the EPTHET-1 FM and EPTHET-2 PFM EMC test campaign.

Requirement	Test	Reference name	Sub section
EMC start test ***EIDA R-777*** ***EIDA R-107*** ***EIDA R-308*** ***EIDA R-309***	Bonding and grounding	Bonding and grounding	6.1
EIDA R-318 ***EIDA R-152*** ***EIDA R-166*** ***EIDA R-167*** ***EIDA R-847*** ***EIDA R-477***	Conducted emission, inrush current on power lines	Inrush current	6.2
EIDA R-314 ***EIDA R-708***	Conducted emission on power lines, common mode, frequency domain, 30 Hz — 100 MHz Background noise: Conducted emission, common mode, frequency domain, 100 Hz — 100 MHz	CE-CM-FD	6.3
EIDA R-313	Conducted emission on power lines differential mode, frequency domain, 30 Hz — 100 MHz	CE-DM-FD	6.4
EIDA R-317 ***EIDA R-473***	Conducted emission on power lines, common mode, time domain	CE-CM-TD	6.5
EIDA R-315 ***EIDA R-316*** ***EIDA R-472*** ***EIDA R-474*** ***EIDA R-475***	Conducted emission on power lines differential mode, time domain	CE-DM-TD	6.6
EIDA R-324 ***EIDA R-484***	Radiated emissions, **Modified as [AD-08]: 14 kHz — 1 GHz and X Band notch.**	RE	6.7
EIDA R-706 ***EIDA R-785***	Emissions, AC Electric Field, **Modified as [AD-08]: 2 kHz — 20 MHz [AD-08].**	E-filed characterization	6.8
EIDA R-703 ***EIDA R-704*** ***EIDA R-705*** ***EIDA R-783*** ***EIDA R-784***	Emissions, AC Magnetic Field, 10 Hz — 1 MHz **Modified as [AD-08]:** **Z-axis for sensor, [-X] face of EPTHET-1 FM at 1m and 2.75m.** **Z-axis for sensor, [+Y] face of EPTHET-2 PFM at 1m and 2.9m.**	H-field characterization	6.9
EIDA R-796 ***EIDA R-680*** ***EIDA R-681*** ***EIDA R-682*** ***EIDA R-842*** ***EIDA R-773***	DC magnetic fields and moments and demagnetization	DC magnetic properties and demagnetization	6.10

1.2 Scope

This document applies to all activities related to EPTHET-1 FM and EPTHET-2 PFM EMC test campaign performed by all institutions and personnel involved in the test.

2 GLOSARY AND DEFINITIONS

2.1 Acronyms and abbreviations

BOB	Break Out Board
CAU	Christian-Albrechts-Universität zu Kiel
CE	Conducted Emission
CM	Common Mode
CS	Conducted Susceptibility
DFU	Derivate For Unit
DM	Differential Mode
EGSE	Electrical Ground Support Equipment
EIDA	Experiment Interface Document-Part A
EPD PO	Energetic Particles Detector Project Office
EPT	Electron, Proton Telescope
EUT	Equipment Under Test
FD	Frequency Domain
FM	Flight Model
HET	High Energy Telescope
ICU	Instrument Control Unit
LCL	Latching Current Limiter
LISN	Line Impedance Stabilization Network
N/A	Not applicable
NCR	Nonconformance Report
PA	Product Assurance
PFM	Protoflight Model
PQM	Proto-Qualification Model
QA	Quality Assurance
RPW-SCM	Radio and Plasma Waves Experiment-Search coil Magnetic sensor
S/C	Spacecraft
TBC	To Be Confirmed
TD	Time Domain
ADS	Airbus Defence & Space

3 APPLICABLE AND REFERENCE DOCUMENTS

3.1 Applicable documents

ID.	Title	Reference	Iss./Rev.	Date
AD-1	Experiment Interface Document part A	SOL-EST-RCD-0050	5/0	16/03/2015
AD-2	EPD EMC Control Plan	SO-EPD-PO-PL-0004	4/0	25/07/2013
AD-3	E-field and H-field characterization Test Procedure Guidelines	SOL.S.ASTR.TN.00252	3	15/01/2015
AD-4	Solar Orbiter EMC Test Procedure Guidelines	SOL.S.ASTR.TN.00273	1	08/01/2015
AD-5	EPTHET1 FM and EPTHET-2 PFM Functional test plan and procedure	SO-EPD-KIE-TP-0038	1/0	29/02/2016
AD-6	CIDL-ABCL for EPTHET-1 FM and EPTHET-2 PFM	SO-EPD-KIE-LI-0011	1/0	29/02/2016
AD-7	Solar Orbiter EMC working group-meeting #11	SOL.S.ASTR.MN.01672		25, 26 /03/2015
AD-8	• Telecon minutes of “EPD EPT-HET-STEP EMC FM testing” • Updated after telecom: “EPD Instrument EMC Test Coverage Summary_FM_PFM_02.xlsx” by Philippe Laget.	SO-EPD-PO-MN-0214	1/0	15/02/2016

3.2 Normative documents

ID.	Title	Reference	Iss./Rev.	Date
NR-08	Spacecraft charging	ECSS-E-ST-20-06C		31/08/2008
NR-09	Electromagnetic compatibility	ECSS-E-ST-20-07C	Rev.1	07/02/2012
NR-10	Electromagnetic compatibility handbook	ECSS-E-HB-20-07A		05/09/2012

3.3 Reference documents

ID.	Title	Reference	Iss./Rev.	Date
RD-1	EPT-HET and STEP Assembly, Integration and Test Plan	SO-EPD-KIE-PL-0010	2/1	30/10/2013
RD-2	Harness Specification	SOL-EPD-PO-RS-0005	1/0	22/07/2012
RD-3	ICU WCA report	SO-EPD-ICU-AN-0002	4/0	05/11/2013
RD-4	Email Subject: EPT-HET PQM docs for TRR	Alfonso Muñoz alfonso.munoz@sener.es		06/04/2015
RD-5	Email Subject: EPT-HET PQM docs for TRR	Alfonso Muñoz alfonso.munoz@sener.es		10/04/2015
RD-6	Email Subject: EPT-HET PQM docs for TRR	Alfonso Muñoz alfonso.munoz@sener.es		13/04/2015

4 TEST OVERVIEW

4.1 Test objectives

The objectives of the different EPTHET-1 FM and EPTHET-2 PFM EMC tests are to:

- Demonstrate the adequacy of the electromagnetic compatibility of EPTHET-1&2 according to the S/C requirements.

EPTHET-1 FM and EPTHET-2 PFM are deliverable unit to ESA/ADS [RD-1].

4.2 Test facility

The EPTHET-1 FM and EPTHET-2 PFM EMC tests are conducted in Airbus Defence & Space Test Laboratories in Portsmouth and in Stevenage, England depending on the tests.

4.3 Environmental conditions

- Temperature*:
- Relative humidity*:
- Cleanliness: ISO 8 clean room entrance to the EMC chamber.

* Environmental condition to be recorded in the test report.

4.4 Test documentation

A completed test report will be presented after the test. It will include the final as-run test procedure approved by the PA (Product Assurance) responsible and the EPD EMI control engineer and will be accompanied by the test report from the test facility. Also, appropriate discussion will conclude the success/failure of the conducted test.

- The complete list of the test equipment and their calibration information will be included in in the final test report.

- Test anomalies will be reported in the final test report as part of the test documentation and in the form of NCR/RFD when applicable.

- Test deviations will be reported in the final test report as part of the test documentation and in the form of NCR/RFD when applicable.

4.4.1 Inrush current test date presentation requirements

In general according to paragraph 5.2.9.4 of [NR-09] and in specific based on guidelines from [AD-4].

4.4.2 Emission data presentation requirements

In general according to paragraph 5.2.9.4 of [NR-09] and in specific based on guidelines from [AD-3] and [AD-4].

4.5 Participants

The test participants and their responsibilities are defined in Table 4-1.

Table 4-1. Test participants (TBC before the test) and their responsibilities.

#	Name	Responsibility
1	Ali Ravanbakhsh	AIVT (Test responsible)
2	Michael Richards	Quality assurance
3	Shri Kulkarni	Instrument lead
4	Sebastian Boden and Jan Tammen	Instrument scientists
5	Mahesh Yedla	Electronics engineer
6	Moritz Juengling	Electronics engineer
ADS (test facility)		
#	Name	Responsibility
1	Jamie Mills	Test facility, Portsmouth
2	Maxsim Pudney and Goodwell Kapfunde	Test facility, Stevenage

4.6 Safety

Handling, mounting and testing shall be performed by qualified personnel from CAU with support of ADS personnel in accordance with safety requirements of ADS.

4.7 Equipment under test

The EPT-HET unit consists of two sensor heads and one Ebox. As seen in Fig. 4-1, the EPT and HET share a common Ebox. The EMC tests are only applicable to the instrument main 25 pin connector and the 15 pin connector for the survival heaters shall not be verified separately [RD-5].

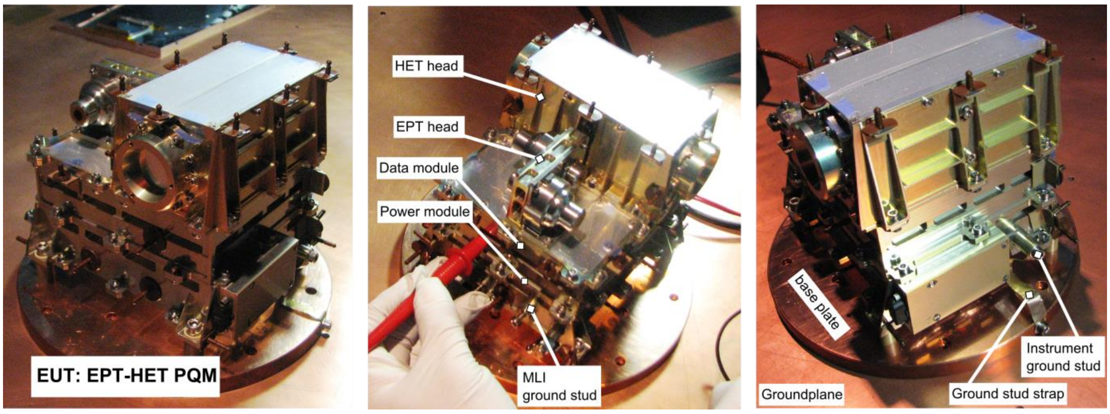


Fig. 4-1. EPTHET PQM is shown above, EPTHET-1 FM and EPTHET-2 PFM are currently under assembly, detail information about EPTHET-1 FM and EPTHET-2 PFM can be found in [AD-6].

4.7.1 EUT modes

- Passive mode: Instrument OFF, GSE ON
- Active mode: Instrument ON (operational), GSE ON

4.7.2 EUT build standard requirement

Please see the details of the EPTHET-1 FM and EPTHET-2 PFM built standard in [AD-6].

5 TEST PARAMETERS

5.1 General set-up requirements

The following requirements from [AD-1] should be respected for all the tests.

EIDA R-460: *The PI shall ensure that the tests shall be performed in an ambient electromagnetic environment which is at least 6 dB below the performance levels required in chapter 4 of [AD-1].*

EIDA R-463: *The PI shall ensure that, in the cases where real electrical/electronic loads cannot be used, these loads are simulated by dummy loads with similar characteristics.*

EIDA R-464: *The PI shall not take the interface wires to ground if not done in the actual/final installation in the spacecraft.*

EIDA R-465: *The PI shall ensure that the power sources used for the tests have well defined impedance below 10 MHz.*

EIDA R-466: *The PI shall ensure that the test harnesses are flight representative.*

EIDA R-467: *The PI shall ensure that the grounding of interfaces is in accordance with flight installation.*

EIDA R-468: *The PI shall ensure that bonding of units, unit tester, etc to the ground plane are verified by a bonding test.*

EIDA R-469: *The PI shall ensure that the unit bonds are similar to that specified for the actual installation.*

EIDA R-470: *The PI shall ensure that all equipment used for emission and susceptibility tests are calibrated.*

EIDA R-471: *The PI shall ensure that passive equipment, such as antennas, current probes etc. have calibration curves from the manufacturer.*

5.2 Ambient conditions, Ref: Section 4.2 of [AD-4]

In order to have a reference, the ambient levels shall be measured. The ambient measurements are defined as the background emission levels, when:

a) All the function and supervisory units of the EGSE are powered and in operation.

b) The EUT is non-powered.

c) A resistive load is connected to the Test Equipment with a load corresponding to the power consumption of the equipment under test.

d) During the ambient measurements a LISN according to **Fig. 6-10-3** shall be connected to the power terminal of the resistive load.

e) The ambient electromagnetic emission levels shall be at least 6 dB below the specified limit.

In the event that the ambient measurements exceed the relevant limit-6dB every effort shall be made to reduce or eliminate those emissions, if this cannot be achieved the source of the emissions should be identified and reported in the EMC Test Report. It should be noted that it may be necessary to address the configuration of the test equipment and its harnessing, as far as possible this should also be installed such that ground loops are minimized, harnesses may require to be over-shielded, aluminum foil can be used for this if necessary.

The impedance of power sources providing input power to the EUT shall be controlled by Line Impedance Stabilization Network(s) (LISN(s)) for all measurement. LISN's shall not be used on output power leads.

5.3 Abortion criteria

The test abortion is possible according to the test facility ADS considerations during the EPTHET-1 FM and EPTHET-2 PFM EMC test campaign.

5.4 Test tolerances

EIDA R-440: *The PI shall respect the following test tolerances, unless otherwise specified.*

- *Voltage Amlplitude: ±5% of the peak value*
- *Current Amplitude: ±5% of the peak value*
- *Frequency: ±2%*
- *Distance: ±5% of specified distance or ±5 cm, whichever is greater*

5.5 Emission bandwidth and measurement

Conducted emission bandwidth and measurement time are indicated in Table 5-1.

Table. 5-1. Bandwidth and measurement time, **Ref: Section 5.2.9 of [NR-09].**

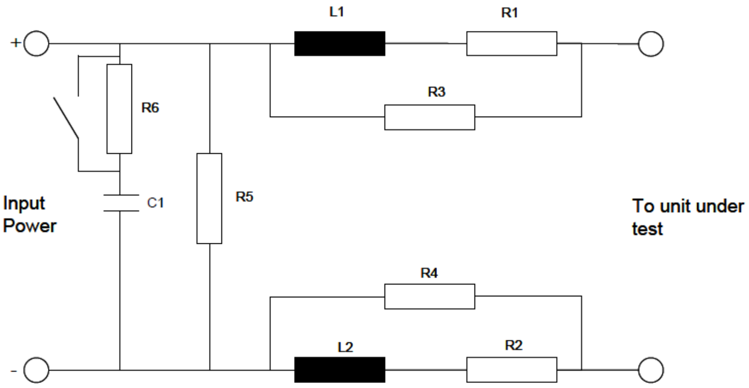
Frequency Range	6 dB bandwidth	Dwell time	Minimum measurement time (analogue measurement receiver)
30 Hz — 1 kHz	10 Hz	0.15 s	0.015 s/Hz
1 kHz — 10 kHz	100 Hz	0.015 s	0.15 s/kHz
10 kHz — 150 kHz	1 kHz	0.015 s	0.015 s/kHz
150 kHz — 30 MHz	10 kHz	0.015 s	1.5 s/MHz
30 MHz — 1 GHz	100 kHz	0.015 s	0.15 s/MHz
Above 1 GHz	1 MHz	0.015 s	15 s/GHz

5.6 LISN (Line Impedance Stabilization Network)

EIDA R-168: *The PI shall ensure that the unit are powered by using the Line Impedence Stabilisation Network (LISN) when switching it ON with an external bounce-free relay (e.g. laboratory mercury relay) installed between the LISN and the user on the positive power line, as shown in figure below.*
D: *The Prime Contractor will specify the LISN characteristics. The LISN will be provided by the PI.*

EIDA R-176: *The PI shall ensure that for all conducted emission and susceptibility tests on subsystem and unit level a LISN is used, simulating the Solar Orbiter primary power bus impedance.*

LISN definition can be seen in Fig. 5-7-1. This LISN shall be used for all the conducted emission and susceptibility test at unit level [AD-2].



R1,R2 = 0.3 Ohm +/-5% for regulated power bus
= 0.1 Ohm +/-5% for unregulated power bus
R3,R4 = 50 Ohm +/-5%
R5 = 50kOhm +/-5%
R6 = 10 Ohm precharge resistor (tbc by contractor)
C1 = 20mF +/-5%
L1,L2 = 2µH +/-5%

Fig. 5-1. LISN definition, **Ref: EIDA R-168 from [AD-1].**

CAU uses the modified LISN received from EPD PO for EPTHET EM EMC test campaign, see Fig. 5-2. The list of modifications can be seen in Table 5-3.

Fig. 5-2. LISN used for EPTHET EM EMC test campaign.

Table 5-3. List of changes CAU applied to the LISN received from PO.

#	**Applied changes**
1	A new label was printed and attached for charging the capacitors.
2	The MDM connector has been changed to one with appropriate mounting screws.
3	On the D-25 connector, the wires for +28V and return were swapped (pins 1 and 14). These wires were resoldered from the connector and returned back to the right order.
4	The top plate of the LISN was modified to let the BOB access from the outside of the LISN. See Fig. 5-5-2.
5	An electronic switch was used for connection with BOB. See the small box in the right side of Fig. 5-5-2.

The final confirmed circuit layout can be seen in Fig. 5-3**.**

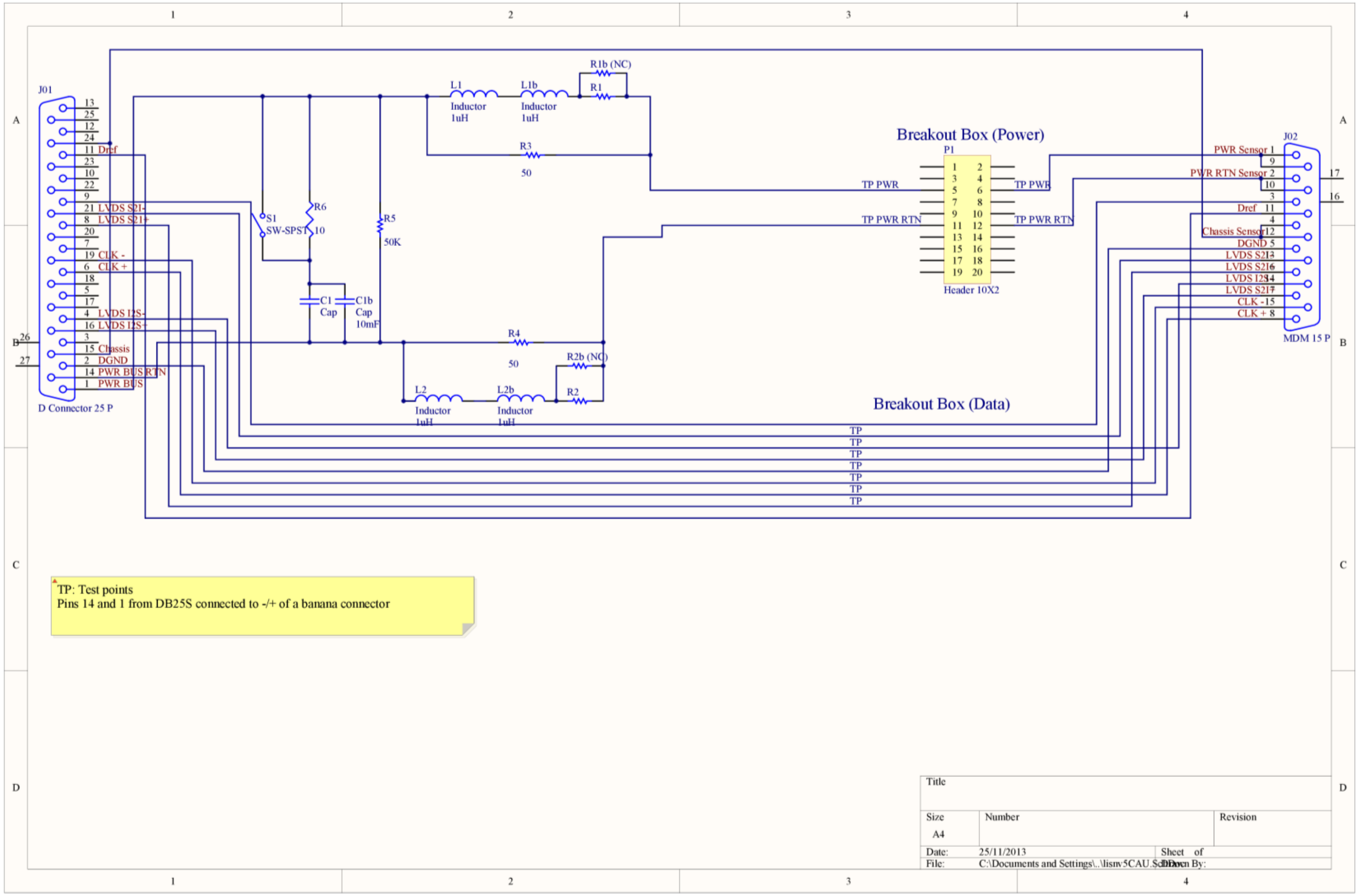


Fig. 5-3. LISN circuit layout.

5.7 Test harness

For the EPTHET-1 FM and EPTHET-2 PFM, the 2 m harness received from EPD PO for the EM units will be used. It is confirmed by EPD PO that EM harness is modified based on [RD-4] and [RD-6] and considered to be as flight representative. The modification to EM harness is wrapping the harness with aluminized kapton. The connectors back shells at both ends are connected to the aluminized side of the added aluminized kapton tape. The modified harness can be seen in Fig. 5-4. This modified EM harness was used in EPTHET PQM EMC test campaign.

The harness pinout and grounding connections can be seen in Fig. 5-4.

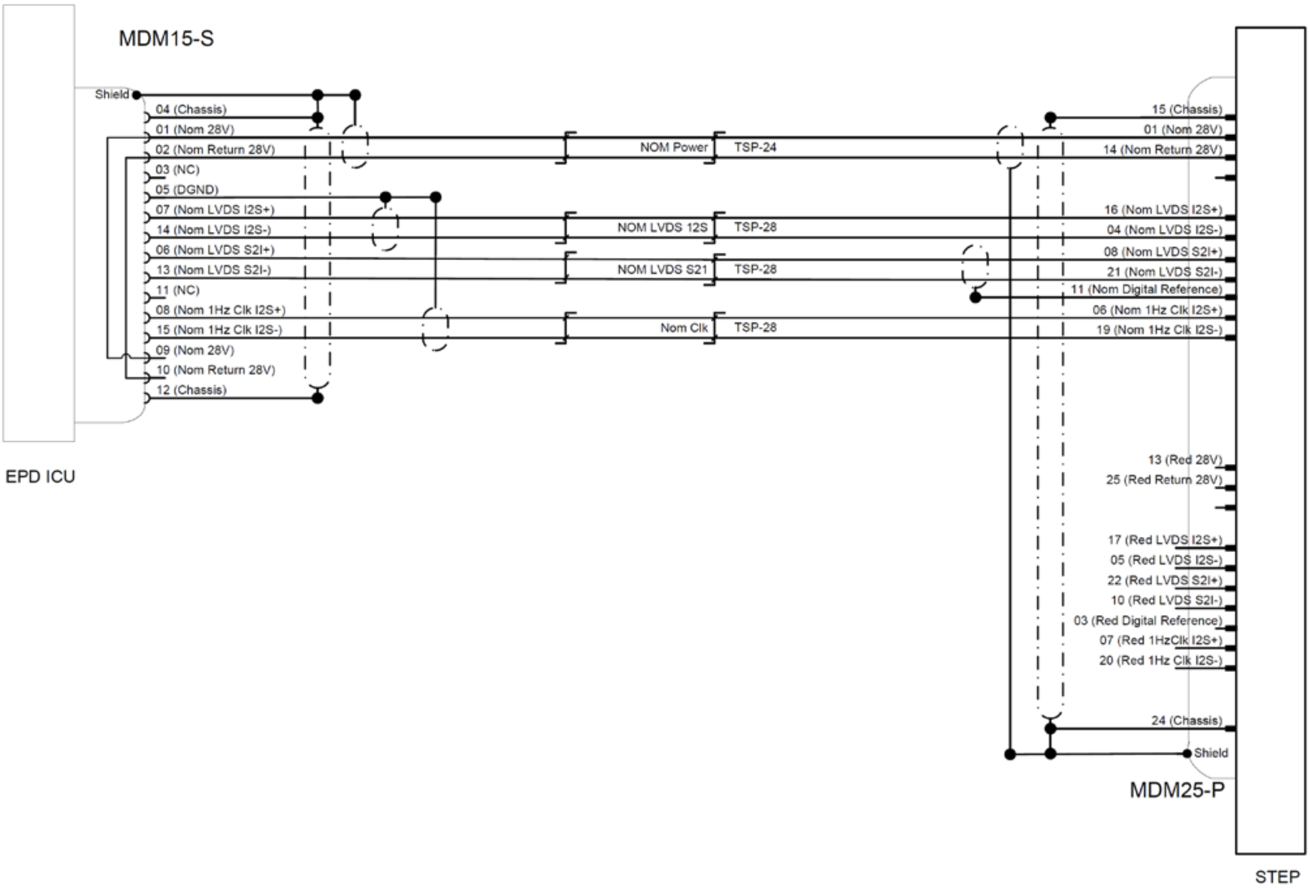


Fig. 5-4. ICU (LISN in unit level EMC tests) to EPTHET pinouts and grounding for EPTHET EM **[RD-2].**

6 EPTHET-1 FM AND EPTHET-2 PFM EMC TESTS

The following tests indicated in Table 1-1 in the introduction (repeated here) are planned for the EPTHET-1 FM and EPTHET-2 PFM EMC test campaign.

Repeated from introduction: **Table 1-1.** Planned tests for the EPTHET-1 FM and EPTHET-2 PFM EMC test campaign.

Requirement	Test	Reference name	Sub section
EMC start test ***EIDA R-777*** ***EIDA R-107*** ***EIDA R-308*** ***EIDA R-309***	Bonding and grounding	Bonding and grounding	6.1
EIDA R-318 ***EIDA R-152*** ***EIDA R-166*** ***EIDA R-167*** ***EIDA R-847*** ***EIDA R-477***	Conducted emission, inrush current on power lines	Inrush current	6.2
EIDA R-314 ***EIDA R-708***	Conducted emission on power lines, common mode, frequency domain, 30 Hz — 100 MHz Background noise: Conducted emission, common mode, frequency domain, 100 Hz — 100 MHz	CE-CM-FD	6.3
EIDA R-313	Conducted emission on power lines differential mode, frequency domain, 30 Hz — 100 MHz	CE-DM-FD	6.4
EIDA R-317 ***EIDA R-473***	Conducted emission on power lines, common mode, time domain	CE-CM-TD	6.5
EIDA R-315 ***EIDA R-316*** ***EIDA R-472*** ***EIDA R-474*** ***EIDA R-475***	Conducted emission on power lines differential mode, time domain	CE-DM-TD	6.6
EIDA R-324 ***EIDA R-484***	Radiated emissions, **Modified as [AD-08]: 14 kHz — 1 GHz and X Band notch.**	RE	6.7
EIDA R-706 ***EIDA R-785***	Emissions, AC Electric Field, **Modified as [AD-08]: 2 kHz — 20 MHz [AD-08].**	E-filed characterization	6.8
EIDA R-703 ***EIDA R-704*** ***EIDA R-705*** ***EIDA R-783*** ***EIDA R-784***	Emissions, AC Magnetic Field, 10 Hz — 1 MHz **Modified as [AD-08]:** **Z-axis for sensor, [-X] face of EPTHET-1 FM at 1m and 2.75m.** **Z-axis for sensor, [+Y] face of EPTHET-2 PFM at 1m and 2.9m.**	H-field characterization	6.9
EIDA R-796 ***EIDA R-680*** ***EIDA R-681*** ***EIDA R-682*** ***EIDA R-842*** ***EIDA R-773***	DC magnetic fields and moments and demagnetization	DC magnetic properties and demagnetization	6.10

NOTE:

1- In this test procedure some requirements from **EIDA-i5** have been generated with the same number plus some letters and the termination**-DFU (Derivate For Units)** to trace easily their parent requirements. These **DFU** requirements are from **"EPD EMC Control Plan"** [AD-02].

2- Some test requirements are modified based on the EPTHET PQM EMC test results. The reference [AD-8] is applicable to the EPTHET-1 FM and EPTHET-2 PFM EMC test items.

6.1 Bonding and grounding

6.1.1 Requirements

EIDA R-777: *The PI shall ensure that each electrical equipment chassis can be bonded to structure with a resistance of less than 5mOhm.*

EIDA R-107: *The PI shall ensure that heaters, thermistors and other discrete thermal components are isolated from structure with a resistance higher than 10 MOhm.*

EIDA R-308: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in paragraph 4.2.10 in ECSS-E-ST-20-07C [NR-09].*

EIDA R-309: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in paragraph 4.2.11 of ECSS-E-ST-20-07C [NR-09] and Paragraph 6.3 of ECSS-E-ST-20-06C [NR-08].*

6.1.2 Bonding and grounding test set up

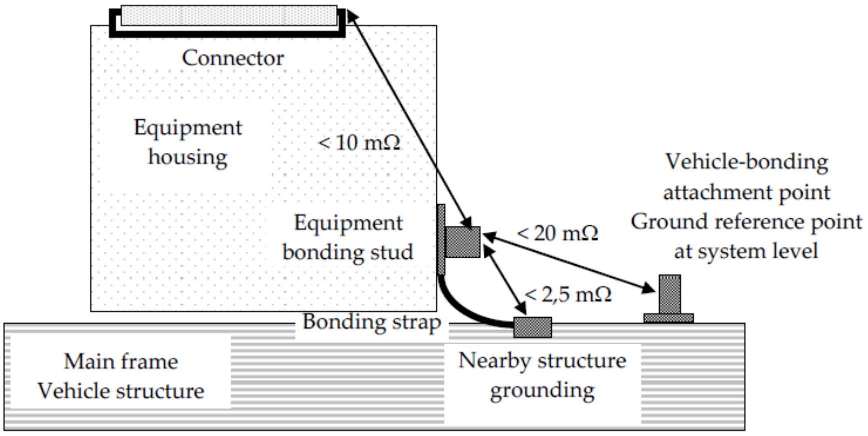


Fig. 6-1-1. Bonding test set up, **Ref: Fig. 4-1of [NR-09].**

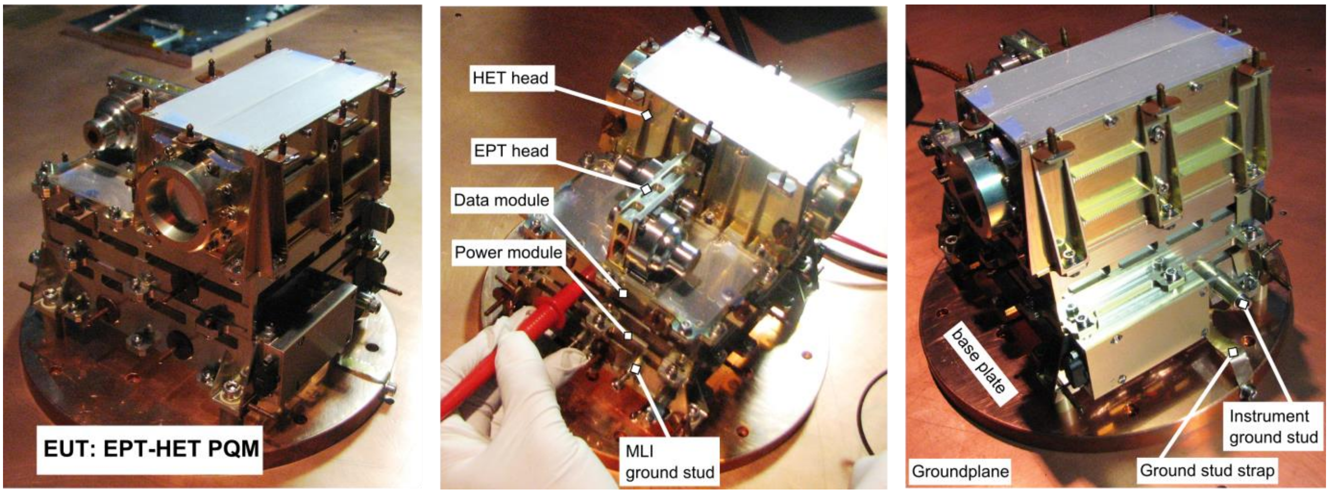
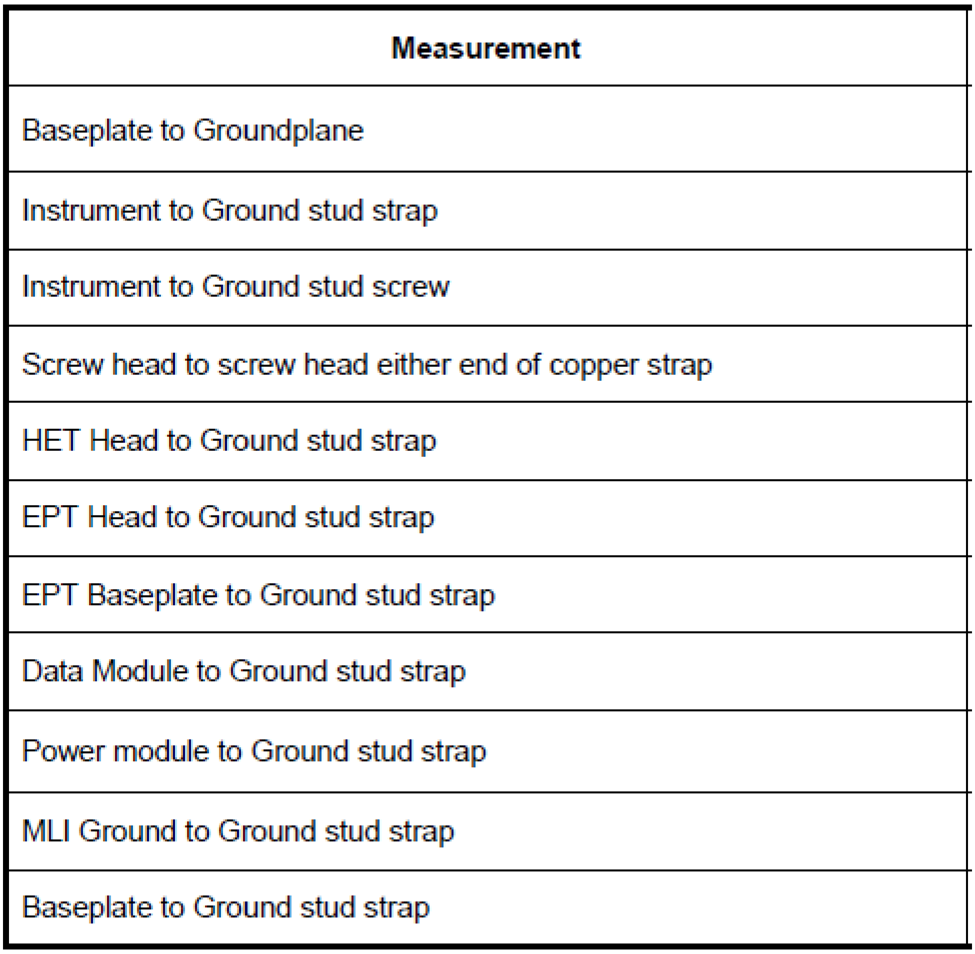


Fig. 6-1-2. Bonding test points, for EPTHET-1 FM and EPTHET-2 PFM the same as EPTHET PQM.

Table 6-1-1. Bonding test end-to-end according to **Fig. 6-1-2**.



Measurement
Baseplate to Groundplane
Instrument to Ground stud strap
Instrument to Ground stud screw
Screw head to screw head either end of copper strap
HET Head to Ground stud strap
EPT Head to Ground stud strap
EPT Baseplate to Ground stud strap
Data Module to Ground stud strap
Power module to Ground stud strap
MLI Ground to Ground stud strap
Baseplate to Ground stud strap

6.1.3 Bonding and grounding step-by-step test procedure

Step	Description	Date/time	Sign	Comment
00	Preparation of the test item according to **Fig. 6-1-1.** • Use of thermal insulators (flight configuration) on the instrument interface with ground table. • Flight like grounding strap.			
05	Measure the resistance between different housing parts according to **Table 6-1-1** and **Fig. 6-1-2.**			
10	Verification of ***EIDA R-107***			
15	Verification of the requirement(s) by test results.			

6.2 Inrush current

6.2.1 Requirements

EIDA R-318: *The PI and Prime Contractor shall comply with the relevant requirements, as defined in Annex A, paragraph A.3 of ECSS-E-ST-20-07C, [NR-09].*

According to [RD-3] and [RD-4]:

*Taking to account the characteristics of the LCL include in the ICU the units shall meet the following values (**EIDA R-318a-DFU**):*
Inrush current duration (in ms): < 6.7 ms
Total Charge: 3.7 mC
Maximum Current during LCL reaction time (15-20 us) shall be less than 10A.
The power bus input interface shall be designed to be compatible with this requirement and a test will be performed to verify the inrush current.

EIDA R-152: *The PI shall ensure that the instruments operate with nominal performance within the following steady state voltage limits provided by the PCDU:*
• Power Bus Voltage = 28 V:
o Min: 26 V
o Max: 29 V
D: *This applies for both Main and Redundant Lines.*

EIDA R-166: *The PI shall measure the Ipeak, the dI/dt and inrush charge considering the maximum and the minimum bus voltage to the loads.*

EIDA R-167: *The PI shall measure the inrush current according to the following set-up*

- *positive power line of each user connected to LCL.*
- *current probe connected near the load*
- *load connections with a limited length.*
- *voltage measure performed near the LISN outlet; performed for engineering analysis /investigation.*

EIDA R-847: *The PI shall measure the lpeak, the dI/dt and inrush charge for the following cases:*

- *When the instrument is connected to a LISN and switched on using an external (test) relay.*
- *If the instrument includes an internal power-on switch, when the instrument is connected to a LISN and this internal switch is operated.*
- *When any other significant transient is expected to be generated, as per PI's assessment.*

EIDA R-477: *The PI shall abide by paragraph 5.4.4 of ECSS-E-ST-20-07C, [NR-09].*

6.2.2 Inrush current test set up

EIDA R-168: *The PI shall ensure that the unit is powered by using a Line Impedence Stabilisation Network (LISN) with an external bounce-free relay (e.g. laboratory mercury relay) installed between the LISN and the user on the positive power line, as shown in Figure 4.7-1 below.*

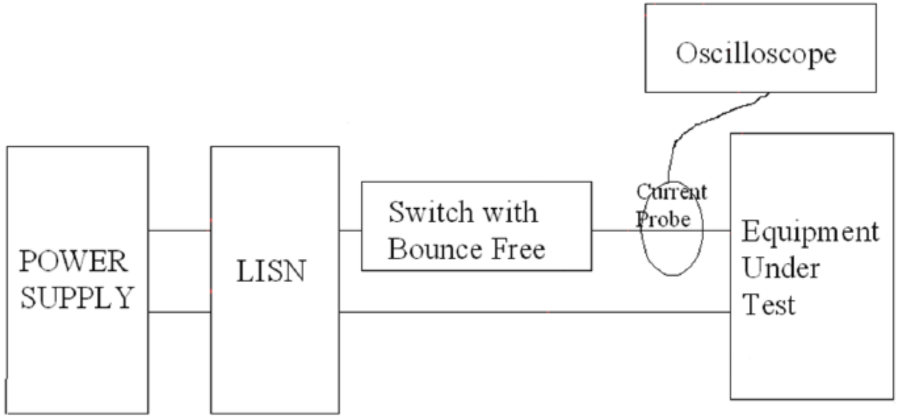


Fig. 6-2-1. Inrush current test set up, **Ref: Fig. 4.7-1 of [AD-1].**

6.2.3 Inrush current step-by-step test procedure, Ref: Section 5.4.4 of [NR-09]

Step	Description	Date/time	Sign	Comment
00	Preparation of test set up according to **Fig. 6-2-1.**			
05	Turn on the measurement equipment and allow a sufficient time for stabilization.			
10	Measurement system checks by the facility responsible.			
15	Test the EUT by determining the conducted emission from the EUT input power leads, as follows: (a) Select the positive lead for testing and clamp the current probe into			

Step	Description	Date/time	Sign	Comment
	position. (b) Perform measurement by application of power on the EUT using a mercury relay. **NOTE** “Inrush current “ should be measured at the minimum and maximum bus voltage as specified at ***EIDA R-166***. Whether significant power transient is expected at mode change, the inrush current shall be measured in the change mode. The voltage evolution during the inrush test has to be recorded. See ***EIDA R-167***.			
20	Calculating the total charge during the inrush. Calculating the current during the reaction time.			
25	Verification of the requirement(s) by test results.			

6.3 CE-CM-FD test

6.3.1 Requirements

EIDA R-314: *The PI and Prime contractor shall ensure that the conducted narrow band current emissions (common mode) in the frequency range 30 Hz - 50 MHz appearing on the unit's primary power lines does not exceed the following limits:*
•60dBuA rms in the frequency range 30Hz to 100kHz,
•Reducing at 15dB per decade to 30dBuA rms in the frequency range 100kHz to 10MHz
•30dBuA rms in the frequency range 10MHz to 50MHz

D: *These limits are applicable to units demanding up to 1A. For units demanding more than 1A the levels may be scaled proportionally to the current demand over the whole frequency range with an increase in dB given by 20 log(I_DC).*

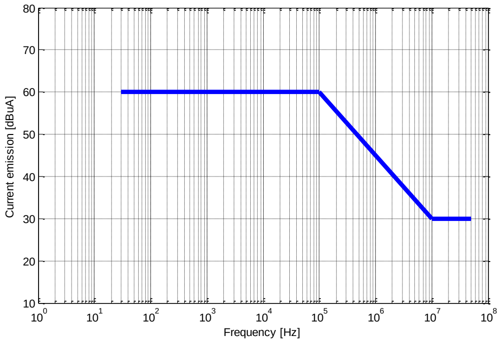


Fig. 6-3-1. EIDA R-314a-DFU graphical representation.

EIDA R-473: *The PI shall abide by paragraph 5.4.3 of ECSS-E-ST-20-07C, [NR-09].*

EIDA R-708: *The PIs shall ensure that Common Mode (CM) current characterization will be performed at unit level to obtain reference information relevant to the RPW desired performance with maximum background noise levels as below and as shown in Figure 9.1-4 (Common mode level):*

- *60dBuV/m over the frequency range 100Hz to 20kHz,*
- *Reducing to 50dBuV/m over the frequency range 10kHz to 20kHz,*
- *Reducing to 20dBuV/m over the frequency range 20kHz to 2MHz,*
- *20dBuV/m over the frequency range 2MHz to 100MHz*

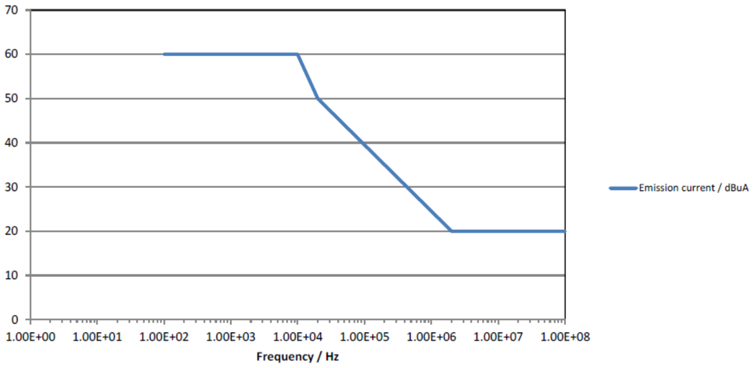
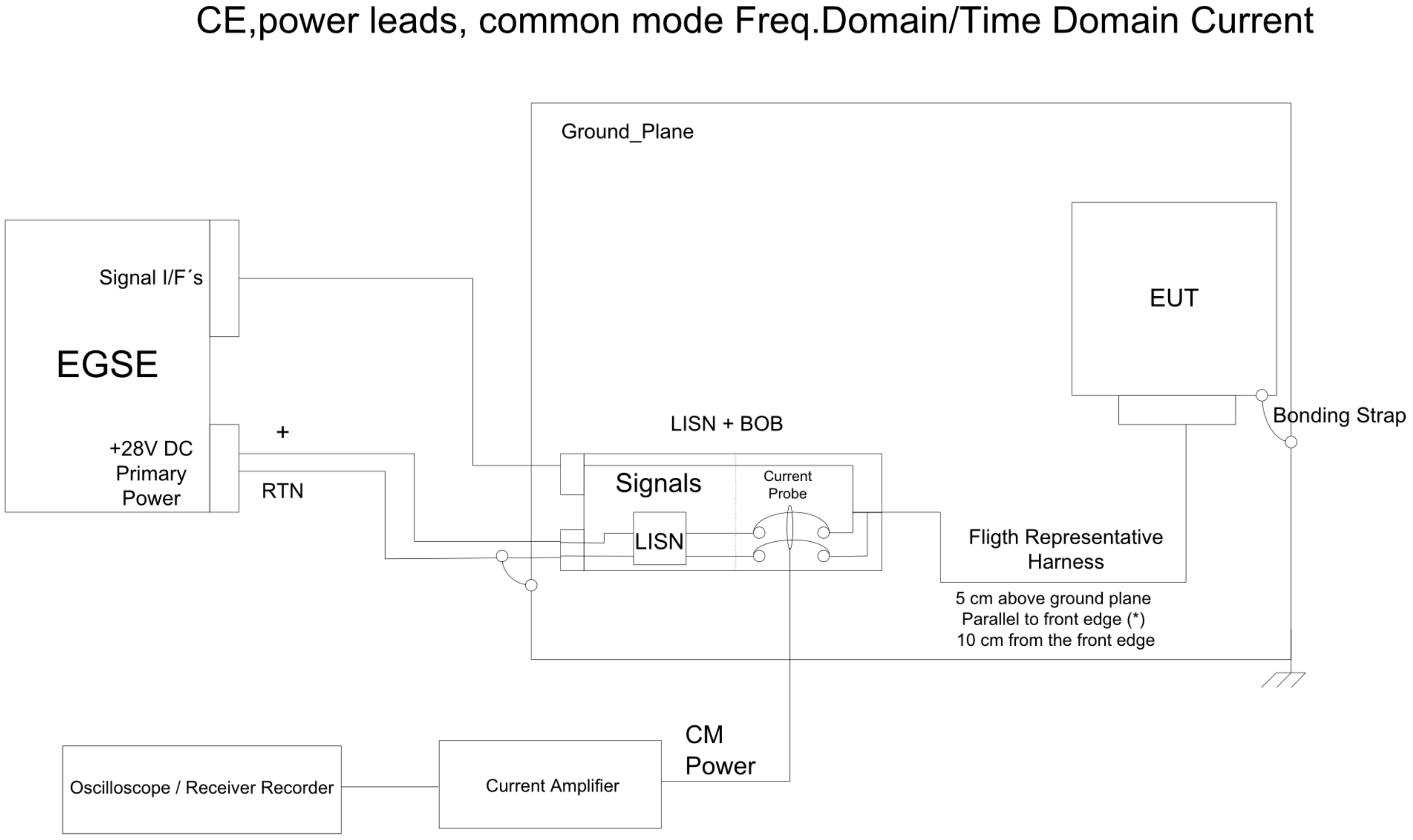


Fig. 6-3-2. Maximum background noise level for current emissions from equipment, **Ref: Fig 9.1-4 from [AD-1].**

6.3.2 CE-CM-FD test set up



(*) If Flight Representative Harness is longer than 2 m the remaining cable length above 2 m shall be routed to the back of the setup and placed in a zigzagged arrangement

Fig. 6-3-3. Test setup for CE-CM-FD.

6.3.3 CE-CM-FD step-by-step test procedure, Ref: Section 5.4.3 of [NR-09]

Step	Description	Date/time	Sign	Comment
00	Preparation of test set up according to **Fig. 6-3-3.**			
05	Turn on the measurement equipment and allow a sufficient time for stabilization.			
10	Measurement system checks by the facility responsible.			
15	Test the EUT by determining the conducted emission from Vbus and VbusRTN lines together (**Fig. 6-3-3.**) (a) Turn on the EUT and wait until it is stabilized. (b) Select a lead or a bundle for testing and clamp the current probe into position. (c) Scan the measurement receiver over the frequency range, using the bandwidths and minimum measurement times specified in **Table. 5-1.** **NOTE** The background noise should be recorded in the test report and this should be in accordance with **EIDA R-708** (see **Fig. 6-3-2**) and **EIDA R-460** (6dB below the requirement).			
20	Verification of the requirement(s) by the test result. Identification of the frequencies in which the peaks appear.			

6.4 CE-DM-FD test

6.4.1 Requirements

EIDA R-313: *The PI and Prime contractor shall ensure that the conducted narrowband current emissions (differential mode) in the frequency range 30 Hz - 50 MHz appearing on the unit's primary power lines does not exceed the following limits:*

- *70dBuA rms in the frequency range 30Hz to 100kHz,*
- *Reducing at 20dB per decade to 30dBuA rms in the frequency range 100kHz to 10MHz*
- *30dBuA rms in the frequency range 10MHz to 50MHz*

D: *These limits are applicable to units demanding up to 1A. For units demanding more than 1A the levels may be scaled proportionally to the current demand over the whole frequency range with an increase in dB given by 20 log (I_DC).*

According to [AD-2]:

EIDA R-313a-DFU: *The EPD units shall ensure that the conducted narrowband current emissions (differential mode) in the frequency range 30 Hz - 50 MHz appearing on the unit's primary power lines does not exceed the following limits:*

- *60dBuA rms in the frequency range 30Hz to 100kHz.*
- *Reducing at 20dB per decade to 20dBuA rms in the frequency range 100kHz to 10MHz.*
- *20dBuA rms in the frequency range 10MHz to 50MHz*

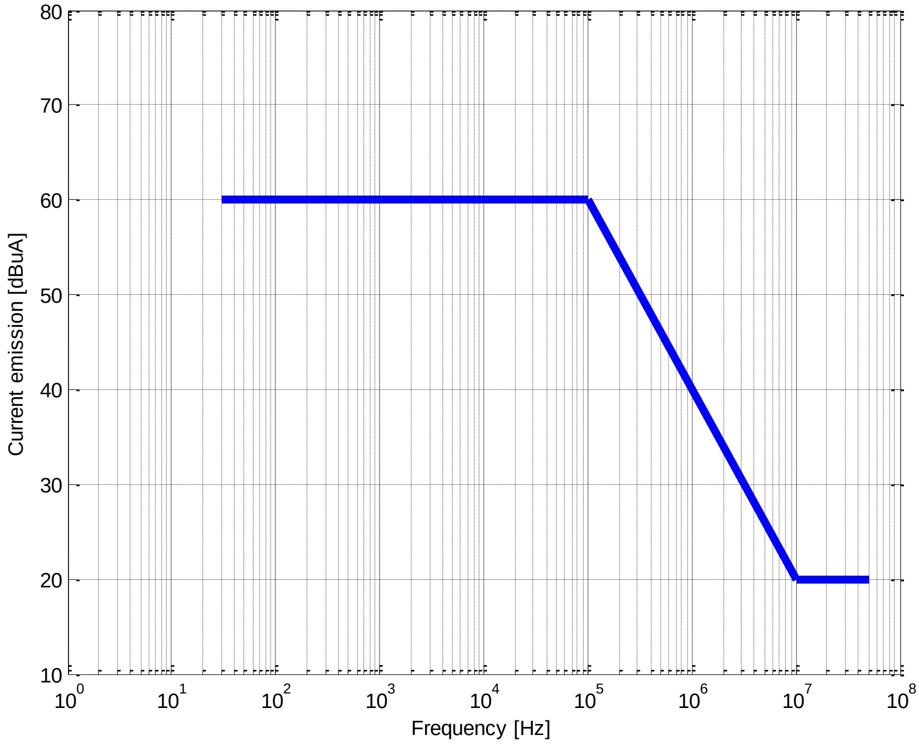
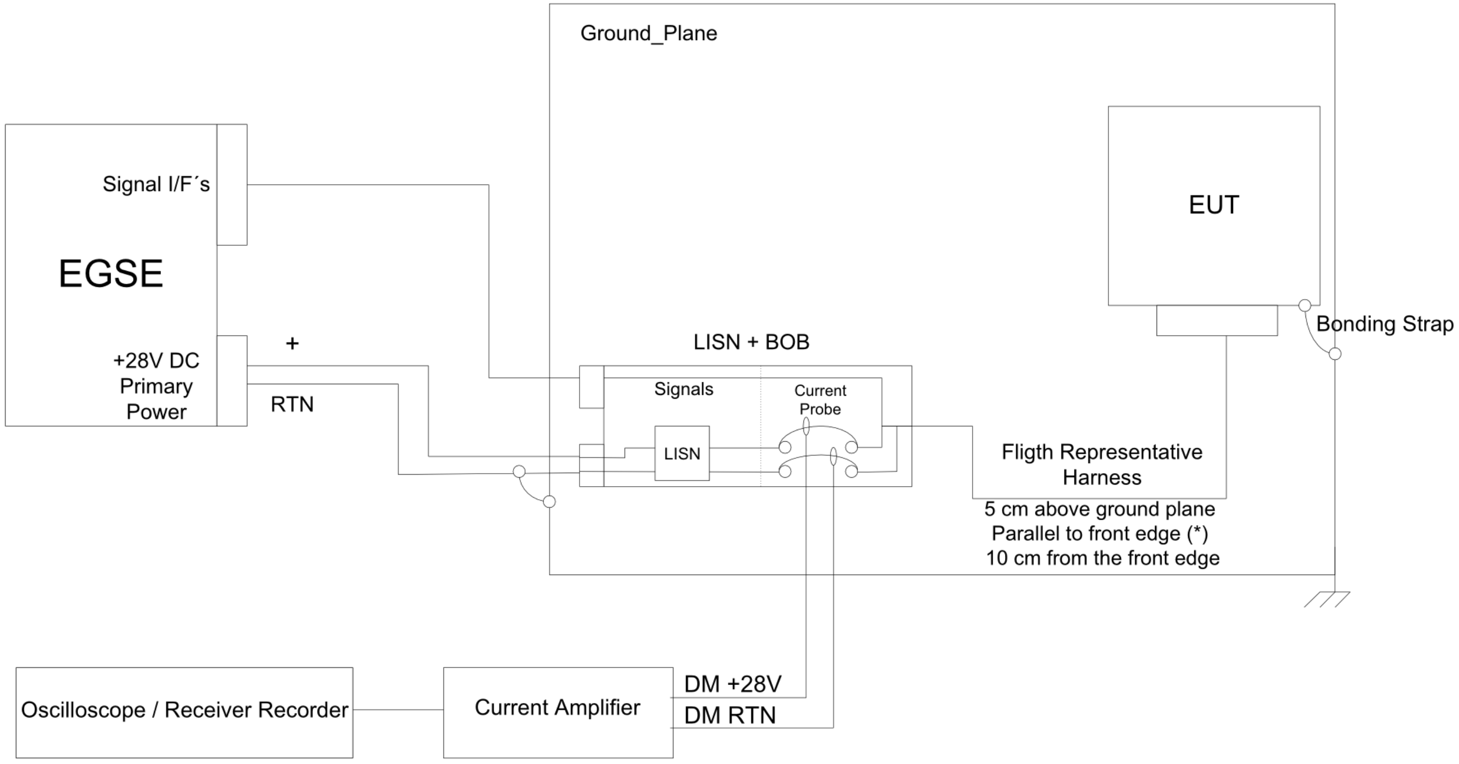


Fig. 6-4-1. EIDA R-313a-DFU graphical representation.

EIDA R-472: *The PI shall abide by paragraph 5.4.2 of ECSS-E-ST-20-07C [NR-09].*

6.4.2 CE-DM-FD test set up

CE,power leads, differential mode .Freq. Domain/Time Domain Transient



(*) If Flight Representative Harness is longer than 2 m the remaining cable length above 2 m shall be routed to the back of the setup and placed in a zigzagged arrangement

Fig. 6-4-2. Test setup for CE-DM-FD.

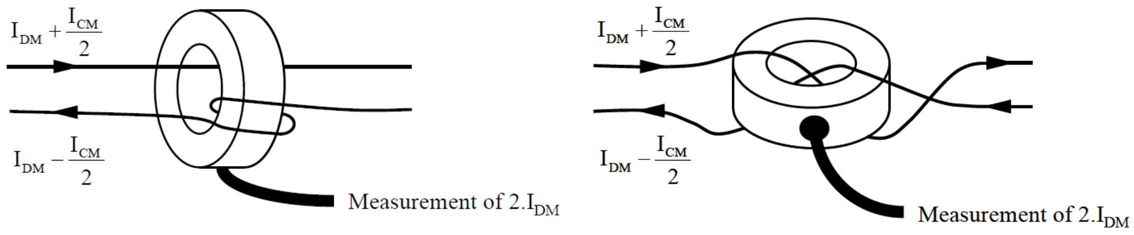


Fig. 6-4-3. **“**True” differential mode current probe set-up, **Ref: Fig. 7-35 of [NR-10].**

6.4.3 CE-DM-FD step-by-step test procedure, Ref: Section 5.4.2 of [NR-09]

Step	Description	Date/time	Sign	Comment
00	Preparation of test set up according to Fig. **Fig. 6-4-2** and **Fig. 6-4-3**.			
05	Turn on the measurement equipment and allow a sufficient time for stabilization.			
10	Measurement system checks by the facility responsible.			
15	Test the EUT by determining the conducted emissions from the EUT input power leads, hot line and return, and measure the conducted emission separately on the power lead as follows: (a) Turn on the EUT and wait for its stabilization. (b) Select a lead or a bundle for testing and clamp the current probe into position. (c) Scan the measurement receiver over the frequency range, using the bandwidths and minimum measurement times specified in **Table 5-1.** **NOTE** The background noise should be recorded in the test report.			
20	Verification of the requirement(s) by the test result. Identification of the frequencies in which the peaks appear			

6.5 CE-CM-TD test

6.5.1 Requirements

EIDA R-317: *The PI and Prime Contractor shall ensure that current ripple and spikes are ≤ 5 mApp when measured with at least 50 MHz bandwidth.*

According to [AD-2]:

EIDA R-317a-DFU: *The EPD Sensors shall ensure that current ripple and spikes are ≤ 1 mApp when measured with at least 50 MHz bandwidth at Sensor/ICU interface. The test at ICU interface will be performed with simulate sensor load.*

EIDA R-473: *The PI shall abide by paragraph 5.4.3 of ECSS-E-ST-20-07C, [NR-09]*

6.5.2 CE-CM-TD step-by-step test procedure, Ref: Section 5.4.3 of [NR-09]

Step	Description	Date/time	Sign	Comment
00	Preparation of test set up according to **Fig. 6-3-3.**			
05	Turn on the measurement equipment and allow a sufficient time for stabilization			
10	Measurement system checks by the facility responsible.			
20	Test the EUT by determining the conducted emission from Vbus and VbusRTN lines together (**Fig. 6-3-3**) (a) Turn on the EUT and wait until it is stabilized. (b) Select a lead or a bundle for testing and clamp the current probe into position. **NOTE** The noise level before the test should be recorded at the test report.			
25	Verification of the requirement(s) by the test result			

6.6 CE-DM-TD test

6.6.1 Requirements

EIDA R-315: *The PI and Prime Contractor shall ensure that current ripple and spikes on the primary power bus inputs of the units, measured on positive and return lines, are ≤ 20 mApp when measured with at least 50 MHz bandwidth.*

EIDA R-316: *The PI and Prime Contractor shall ensure that voltage ripple / spikes on the primary power bus inputs of the units, measured between positive and return lines, are ≤ 150 mVpp (ripple) and ≤ 280 mVpp (spikes) when measured with at least 50 MHz bandwidth.*

According to [AD-2]:

EIDA R-315a-DFU: *The EPD units shall ensure that current ripple and spikes on the primary power bus inputs of the units, measured on positive and return lines, are ≤ 3 mApp when measured with at least 50 MHz bandwidth.*

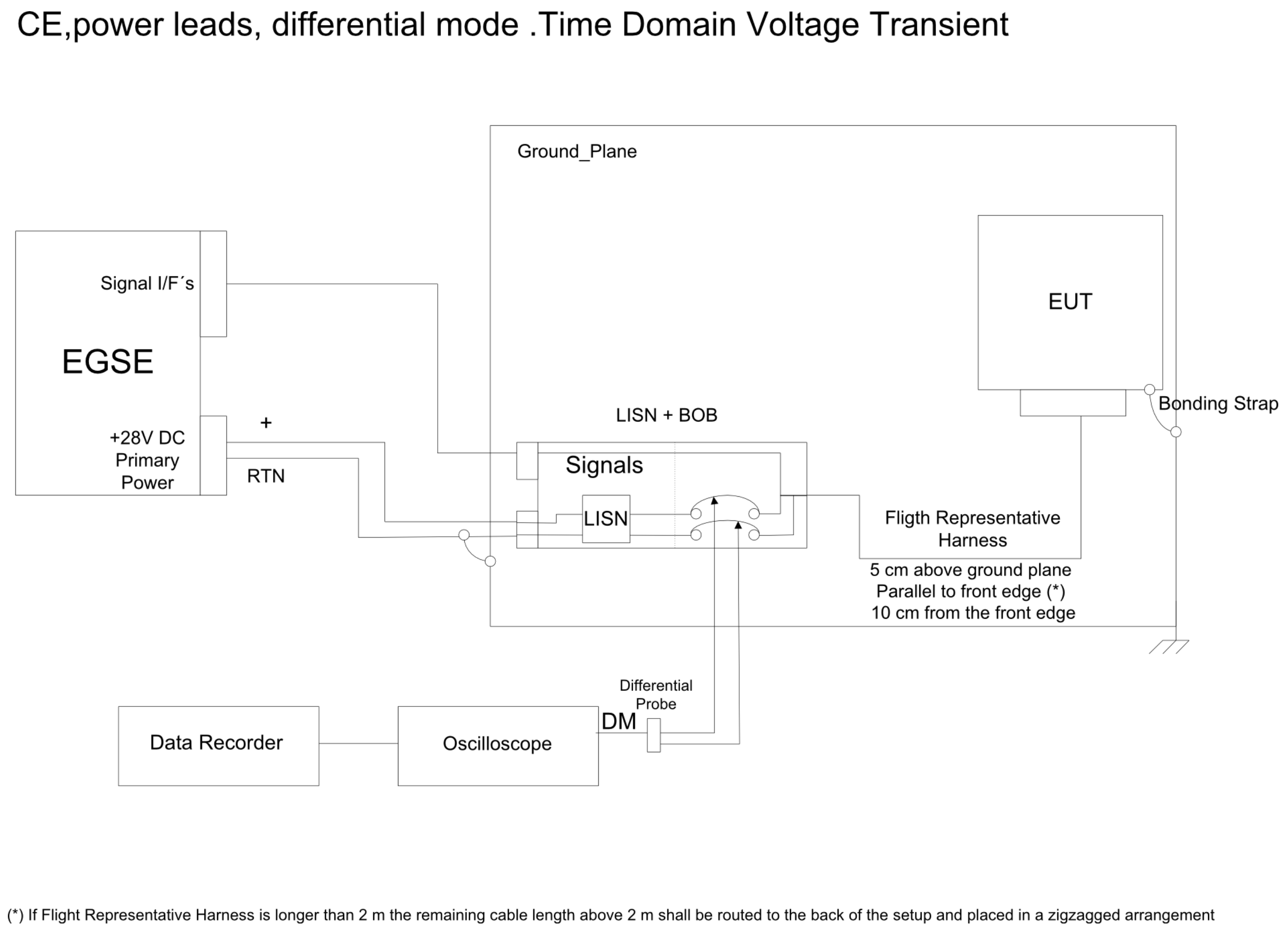
EIDA R-316a-DFU: *The EPD units shall ensure that voltage ripple / spikes on the primary power bus inputs of the units, measured between positive and return lines, are ≤ 25 mVpp (ripple) and ≤50 mVpp (spikes) when measured with at least 50 MHz bandwidth.*

EIDA R-472: *The PI shall abide by paragraph 5.4.2 of ECSS-E-ST-20-07C [NR-09].*

EIDA R-474: *The PI shall measure current ripple and spikes according to the test set-up in fig. 5-8 of ECSS-E-ST-20-07C, [NR-09] with current probe and oscilloscope with the required bandwidth.*

EIDA R-475: *The PI shall measure voltage ripple/spike on the primary power bus inputs of the units according to the test set-up in fig. 5-8 ECSS-E-ST-20-07C, [NR-09] where a differential voltage probe (instead of a current probe) is connected to the power lines wires and the data recorder is an oscilloscope.*

6.6.2 CE-DM-TD test set up



(*) If Flight Representative Harness is longer than 2 m the remaining cable length above 2 m shall be routed to the back of the setup and placed in a zigzagged arrangement

Fig. 6-6-1. Test setup for CE-DM-TD voltage transient.

6.6.3 CE-DM-TD step-by-step test procedure, Ref: Section 5.4.2 of [NR-09]

Step	Description	Date/time	Sign	Comment
00	Preparation of test set up according to **Fig. 6-6-1** for voltage transient.			
05	Turn on the measurement equipment and allow a sufficient time for stabilization.			
10	Measurement system checks by the facility responsible.			
15	Test the EUT by determining the conducted emissions from the EUT Vbus against Vbus Return: (a) Turn on the EUT and wait for its stabilization. (b) Select a lead or a bundle for testing and clamp the differential voltage probe into position. **NOTE** It is recommended that the noise level before the test should be recorded at the test report.			
20	Verification of the requirement(s) by the test result.			
25	Preparation of test set up according to **Fig. 6-6-1** for current transient. Test the EUT by determining the conducted emissions from the EUT in each power line Vbus and VbusRtn: (a) Turn on the EUT and wait for its stabilization. (b) Select a lead or a bundle for testing and clamp the current probe into position. **NOTE** It is recommended that the noise level before the test should be recorded at the test report.			
30	Verification of the requirement by the test result			

6.7 RE test

Modified based on [AD-08]: Only 14 kHz — 1 GHz and X Band notch.

This modification is valid wherever applicable in the step-by-step test procedure in Sec.6-7-3.

Note 1 [AD-8]: FFT function of the receiver can be used in order to speed up the measurement.

Note 2 [AD-8]: It may also be possible to consider decreasing the distance between the instrument and the test antenna and adjusting the limit to be measured accordingly.

6.7.1 Requirements

EIDA R-324: *The PI and Prime contractor shall ensure that the narrow band radiated emissions from the unit in the frequency range 14kHz to 18GHz do not exceed the following limits:*

- *40dBuV/m in the frequency range 14kHz to 100MHz*
- *Increasing at 20dB per decade to 60dBuV/m in the frequency range 100MHz to 1GHz*
- *60dBuV/m in the frequency range 1GHz to 18GHz*
- *Notch 1: 15dBuV/m over the frequency range 7.145GHz to 7.19GHz (on-board command receiver)*

D: *For non RF units which do not feature high frequency clocks, testing of the upper frequency may be limited to 1 GHz or the 10th harmonic (whichever is greater), as long as the 5th - 10th harmonics are at least 10 dB below the limit. However, regardless of this relaxation, Notch 1 shall be verified in all cases.*

EIDA R-484: *The PI shall abide by paragraph 5.4.6 of ECSS-E-ST-20-07C, [NR-09] for frequencies above 30MHz.*

D: *Dealing with the low frequency measurements, a number of precautions are needed to be reproducible. It is necessary to avoid all parasitic resonances of the test set-up, so that measurements are reproducible and the radiated emission of canonical objects can be measured according to prediction.*
D: *Recommended test configurations and test precautions are presented in ECSS-E-HB-20-07A Chapter 7.3.*

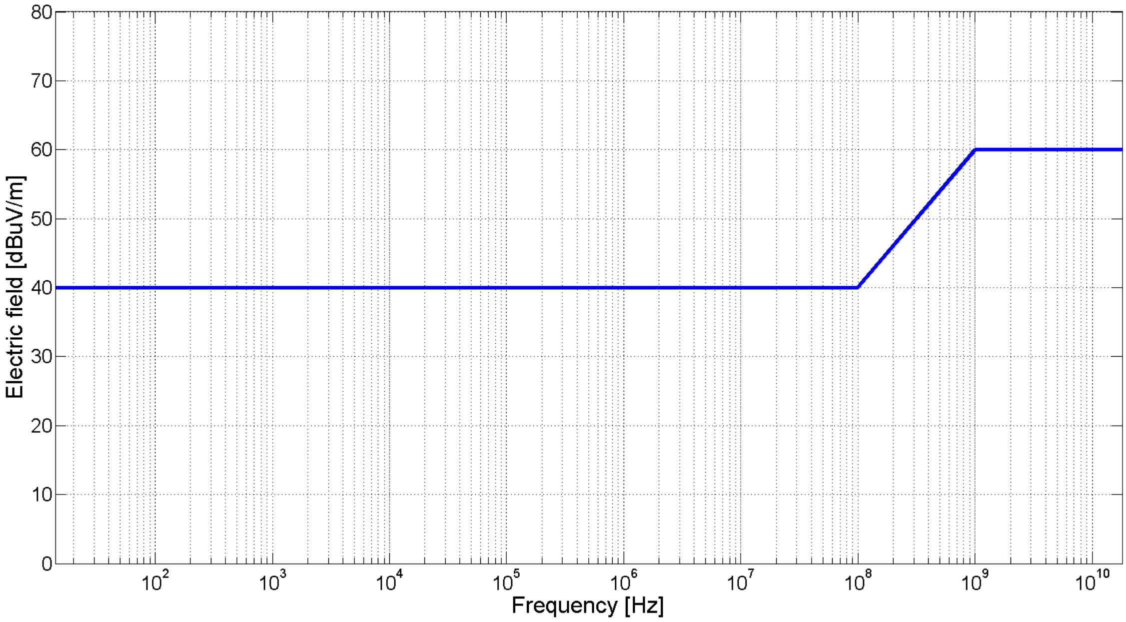


Fig. 6-7-1. EIDA R-324 graphical representation.

Table 6-7-1: X-Band receiver notch requirements. **Ref: Table 7-8 of [AD-4].**

Frequency in MHz	Limit for Internal unit in dBµV/m	Limit for External unit in dBµV/m
7072	60	60
7072	53	23
7122	53	23
7122	38	8
7162	38	8
7162	8	-22
7182	8	-22
7182	38	8
7222	38	8
7222	53	23
7272	53	23
7272	60	60

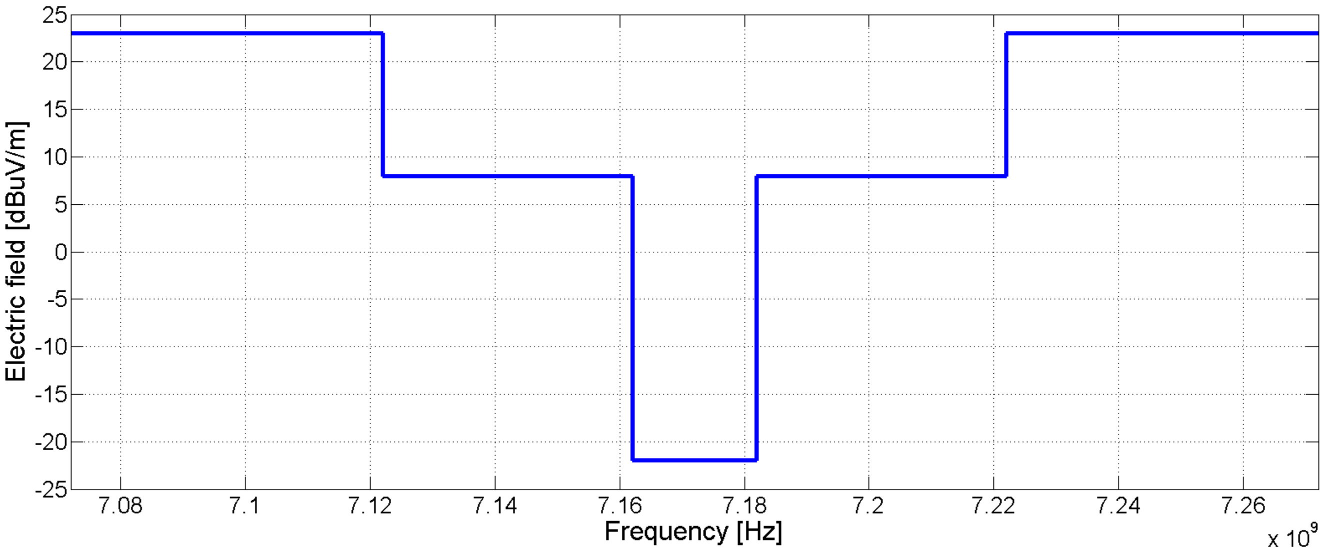


Fig. 6-7-2. X-Band receiver notch requirement graphical representation for **EPTHET1&2 as an external units**, [AD-4].

6.7.2 RE test set up

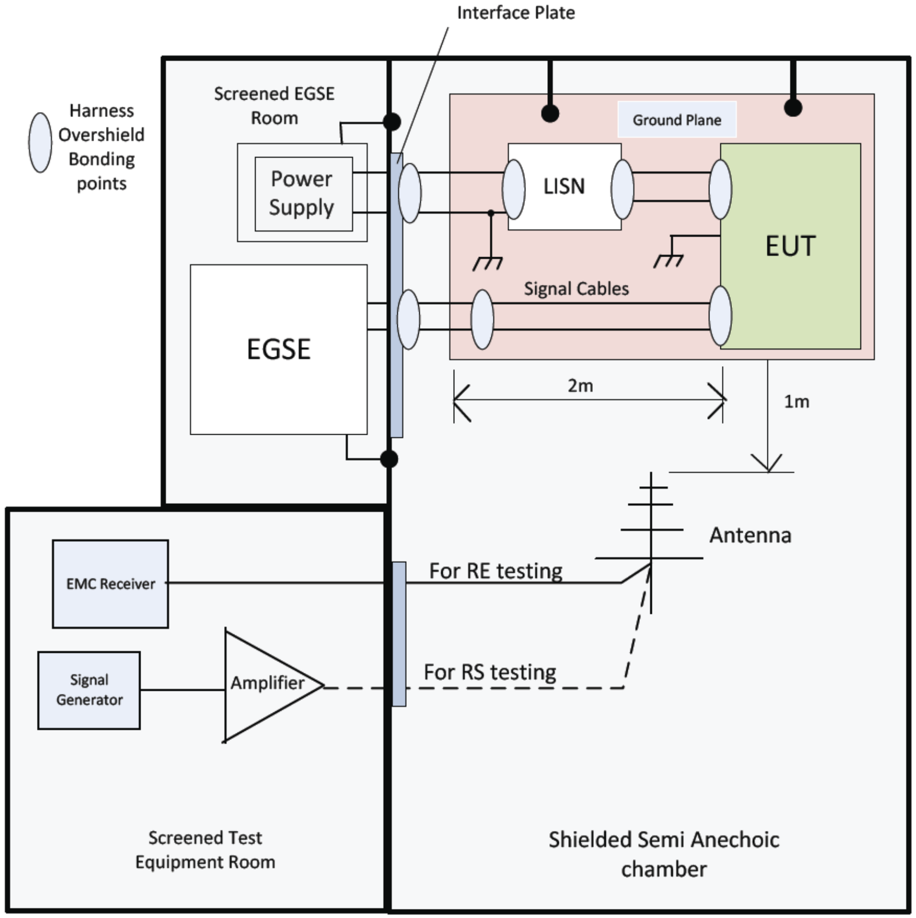


Fig. 6-7-3. Test setup for RE test, **Ref: Fig. 4-2 of [AD-4].**

6.7.3 RE step-by-step test procedure, Ref: Section 7.6.4 of [AD-4]

Step	Description	Date/time	Sign	Comment
00	Preparation of the test equipment according to: See **Section 7.3.1.1 of [NR-10]** for frequencies below 30 MHz See **Section 5.4.6.2 of [NR-09]** for frequencies above 30 MHz			
05	Connect the EUT the EGSE and the EMC test equipment as per the Radiated Emissions Configuration of **Fig. 6-7-3**. Position the antenna 1m from the boundary of the EUT.			
10	Ensure the bonding of the EUT is measured and recorded according the test relevant mode definition. See **section 4.7.1.**			
15	Ensure that the worst case face for emissions is established & that the measurement antenna points towards this face. **NOTE** In the event that unit needs to be re-sited the bonding measurements should be repeated.			
20	Follow the Ambient conditions setup and measurements according to **Section 5.2** ensuring there is adequate margin between the ambient emission and the required limit.			
25	Power on the EUT and allow adequate time for the EUT to stabilize. Set the EUT to the intended mode defined in **section 4.7.1**.			
30	Perform the EUT functional check to ensure the EUT is operating correctly and in the defined mode. Functional check according to **[AD-5]**.			
35	Use the appropriate antenna and the specified bandwidth for the frequency range to be measured scan the specified frequency range.			
40	For frequencies above 30 MHz change the polarity of the EMC antenna.			
	Take a photograph of the equipment setup.			

Step	Description	Date/time	Sign	Comment
45	Change the EMC antenna and receiver bandwidth to the next required frequency band and repeat the measurement until all the frequency bands have been measured over the required frequency range 14 kHz to 18 GHz. **NOTE** In the event that a bandwidth change frequency coincides with that of a dc/dc converter switching frequency then the bandwidth change frequency can be modified to enable the converter switching frequency to be more readily visible giving confidence that the unit is operating correctly – any changes shall be recorded in the EMC test report.			
50	Test conclusion			

6.8 E-field characterization

Modified based on [AD-08]: 2 kHz — 20 MHz [AD-08].

This modification is valid wherever applicable in the step-by-step test procedure in Sec.6-8-2.

6.8.1 Requirements

EIDA R-706: *The Prime Contractor shall ensure that all electrical and electronic equipment units shall be measured to determine the E-field emissions with a background noise level better than reported in figure below (Figure 9.1-2).*
D: *Measurement distance will be defined on a case by case basis. The test set-up shall be photographed in each configuration used.*
D: *Units are defined as external if they are mounted external to or protrude through the spacecraft external shielding structure.*
D: *Units are defined as active if they contain electrical or electronic components and they are powered or operated during the scientific quiet periods of Solar Orbiter orbit.*

EIDA R-785: *The PI shall characterise the radiated E-field emissions of each unit using the frequency ranges and background noise as in Figure below.*
D: *Measurement distance will be defined on a case by case basis. The test set-up shall be photographed in each configuration used.*

NOTE: **EPTHET1&2 are external and active units.**

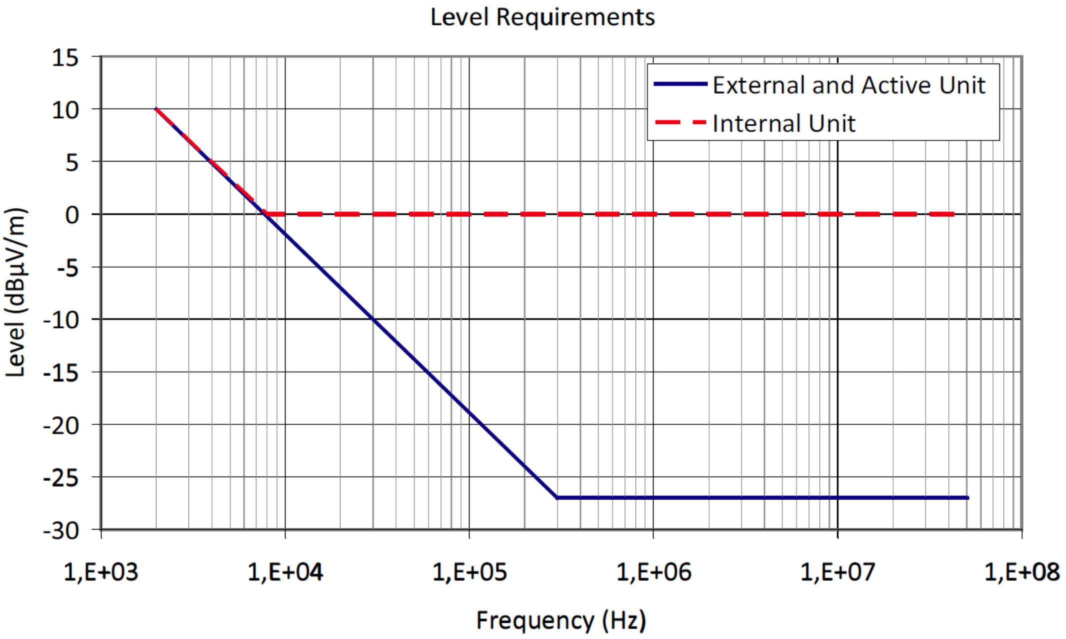


Fig. 6-8-1. Background noise level for radiated E-field measurement, **Ref: Fig. 9.1-2 of [AD-1].**

Table 6-8-1: E-field recommended measurements bandwidths, **Ref: Table 1 of [AD-3].**

Frequency range	Receiver bandwidth	Video bandwidth
2kHz — 10kHz	10Hz	Video filtering shall not be used to limit the receiver response. If a controlled bandwidth is available on the measurement receiver, it shall be set to its greatest value.
10kHz — 40kHz	10Hz	
40kHz — 100kHz	100Hz	
100kHz — 1MHz	100Hz	
1MHz — 50MHz	1kHz	

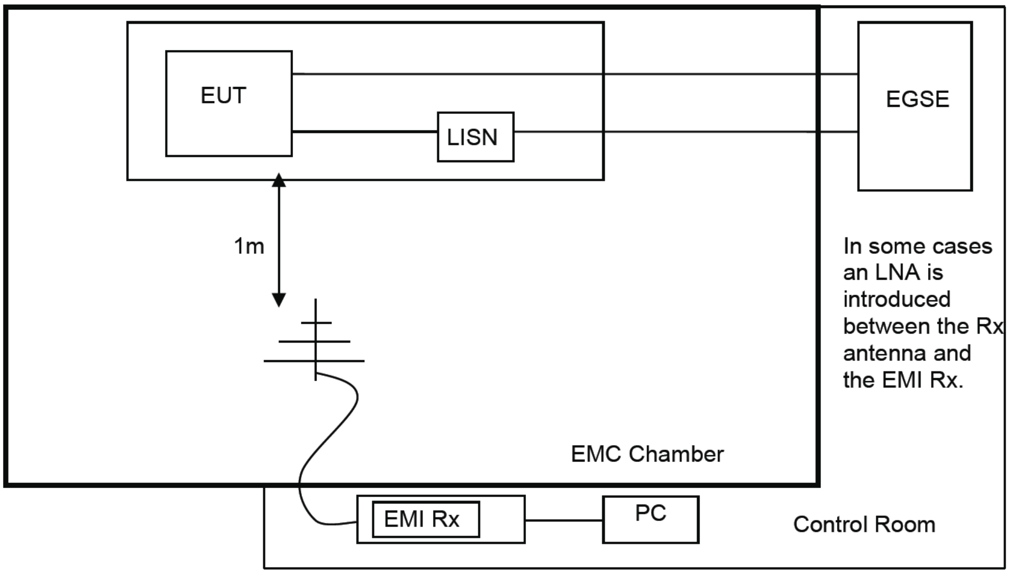
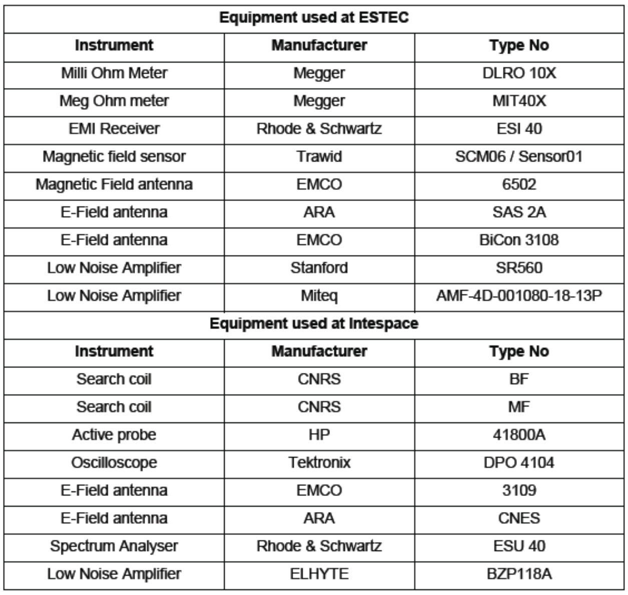


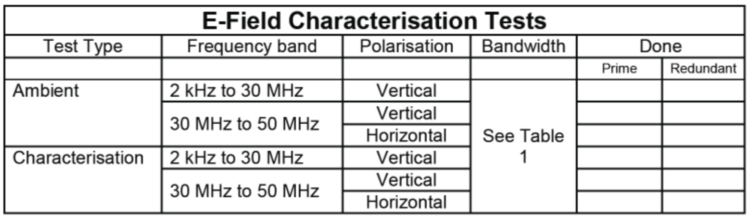
Fig. 6-8-2. E-field characterization test arrangement, **Ref: Fig. 3-4 of [AD-3].**

Table 6-8-2: List of suggested test equipment, **Ref: Table 5 of [AD-3].**



Equipment used at ESTEC		
Instrument	**Manufacturer**	**Type No**
Milli Ohm Meter	Megger	DLRO 10X
Meg Ohm meter	Megger	MIT40X
EMI Receiver	Rhode & Schwartz	ESI 40
Magnetic field sensor	Trawid	SCM06 / Sensor01
Magnetic Field antenna	EMCO	6502
E-Field antenna	ARA	SAS 2A
E-Field antenna	EMCO	BiCon 3108
Low Noise Amplifier	Stanford	SR560
Low Noise Amplifier	Miteq	AMF-4D-001080-18-13P
Equipment used at Intespace		
Instrument	**Manufacturer**	**Type No**
Search coil	CNRS	BF
Search coil	CNRS	MF
Active probe	HP	41800A
Oscilloscope	Tektronix	DPO 4104
E-Field antenna	EMCO	3109
E-Field antenna	ARA	CNES
Spectrum Analyser	Rhode & Schwartz	ESU 40
Low Noise Amplifier	ELHYTE	BZP118A

Table 6-8-3: E-field characterization test check table, **Ref: Section 3.5.1 of [AD-3].**



E-Field Characterisation Tests					
Test Type	Frequency band	Polarisation	Bandwidth	Done	
				Prime	Redundant
Ambient	2 kHz to 30 MHz	Vertical	See Table 1		
	30 MHz to 50 MHz	Vertical			
		Horizontal			
Characterisation	2 kHz to 30 MHz	Vertical			
	30 MHz to 50 MHz	Vertical			
		Horizontal			

6.8.2 Test set up and procedure, Ref: Section 3.4.1 to 3.4.5 of [AD-3]

Step	Description	Date/time	Sign	Comment
00	**Bonding testing** Bonding testing should be performed again according to section 6.1. As a minimum, the following bonding points should be measured and recorded : 1)Equipment Bonding Stud to nearby structure grounding (limit <2.5 mOhms) In the event that a bonding stud is not provided (e.g. a tapped hole or mounting feet expected to be used) then the unit will be bonded to the Test Bench in a manner representative of the spacecraft installation and the measurements taken accordingly. 2) Equipment Bonding Stud to connector(s) housing (limit <10 mOhms) The bonding should be measured using a 4 wire bonding meter which passes a test current of greater than 0.1 A. The bonding should be also be measured with the probes connected in both one direction and then the reverse direction. The results should be recorded for each measurement made.			
05	**Equipment set up** The EUT and EMC test equipment should be set as shown in **Fig. 6-8-2** using the suggested test equipment listed in **Table 6-8-2**. **Note:**			

Step	Description	Date/time	Sign	Comment
	The harness from the unit to the LISN should be exposed to the antenna in at least two meters, see general test set up in **Ref: Fig. 5-3 of [NR-09].** **Note:** Previous testing found, that in order to achieve and measure the low E-Field ambient levels required for this testing, a short bond strap was required to be connected directly to the shield of the input port of the EMI Receiver and connected to the facility ground. Additionally it has been shown that wrapping the cable with Aluminium foil from the input port of the measurement receiver to the test chamber wall and grounding the wrap appropriately also enhances the ambient background achievable. Additional investigations undertaken have shown that it may be necessary to apply good EMC practices to the whole of the test set-up including the EGSE and associated EMC measurement equipment. Points for consideration are: • Ensuring all test cables are optimized to reduce loop areas • Wrapping of EGSE cabling in Aluminum foil – including cables that may be fed through chamber interface ducts. • If bulkheads feed-through are used then any screening should be taken as securely as possible to the bulkhead or the use of backshells employed.			
10	**Ambient Test procedure** **Note:** As this characterization testing is being performed at the sensitivity limits of the test facility and its test equipment it is important to make an initial measurement of the ambient electromagnetic conditions i.e. with the EGSE			

Step	Description	Date/time	Sign	Comment
	ON and the EUT OFF. It may well be necessary to adjust the layout and bonding positions of harnesses etc. to ensure the setup in the chamber closely replicates the final spacecraft installation. This will be discussed and agreed at TRR. Some experimentation with the EMI test equipment grounding and cable locations may also be necessary in order to minimise the ambient noise seen by the test receiver. Set up the equipment as shown in **Fig. 6-8-2.** Take a photograph of the test set-up. With the EUT OFF and the EGSE ON, set the receiver to scan from 2 kHz to 30 MHz using the appropriate bandwidths and measurement times specified in **Table 6-8-1**. Record the results in an amplitude (dBµV/m) versus frequency plot. At 30 MHz stop the scan and change the antenna to one suitable for the 30 to 50 MHz band. Take a photograph and then continue the scan up to 50 MHz. When 50 MHz is reached, stop the scan and plot the results. Change the polarization of the antenna and repeat the measurement from 30 MHz to 50 MHz and record and plot the results. It should be noted that ideally there should be a 6 dB margin between the			

Step	Description	Date/time	Sign	Comment
	ambient levels and the limit guideline in **Fig. 6-8-1** but in practice this may not be achievable. If there are peaks present in the plot greater than the **Fig. 6-8-1** limit guide line minus 6 dB, identify the source (if possible), the frequency and amplitude of these peaks and report them in a table. In order to trace unwanted emissions, it may also be necessary and desirable to make a measurement of the chamber ambient level i.e. with the EGSE OFF and the EUT OFF to confirm that any unwanted emissions that appear in the plots are not due to external sources being coupled into the chamber via the EGSE to EUT cables.			
15	**E-field characterization test procedure, test check list in Table 6-8-3** Set up the equipment as shown in **Fig. 6-8-2.** Take a photograph of the test set-up. With the EUT ON and the EGSE ON set to their worst case operating mode(s) and having had sufficient time to stabilize, set the receiver to scan from 2 kHz to 30 MHz using the appropriate bandwidths and measurement times specified in Table 1. Record the results in an amplitude (dBμV/m) versus frequency plot. At 30 MHz stop the scan and change the antenna to one suitable for the 30 to 50 MHz band. Take a photograph and then continue the scan up to 50 MHz.			

Step	Description	Date/time	Sign	Comment
	When 50 MHz is reached, stop the scan and plot the results. Change the polarization of the antenna and repeat the measurement from 30 MHz to 50 MHz and record and plot the results. Note there are no pass/fail limits with this test, however, every effort must be made to try and ensure that results obtained are the best that they can be within the confines of the test set-up and test facility. In the event that the limit guideline is exceeded then measures such as: • bringing the test harnesses down on to the ground plane and grounding the overall shields at intervals along their length • requesting permission to remove any flight connector savers that may be present or ensuring that these are adequately screened and not contributing to the measurements seen If there are peaks present in the plot greater than the **Fig. 6-8-1** limit guide line minus 6 dB, identify the source (if possible), the frequency and amplitude of these peaks and report them in a table. The results should also be provided in a standard Microsoft EXCEL file format, such as csv, to enable subsequent combination and data processing of the results. Testing should be undertaken with the EUT being operated in Prime and Redundant configurations as applicable and as defined by the EUT test procedure			
20	Test conclusion			

6.9 H-field characterization

Modified based on [AD-08]:

- **Z-axis for sensor, [-X] face of EPTHET-1 FM at 1m and 2.75m.**
- **Z-axis for sensor, [+Y] face of EPTHET-2 PFM at 1m and 2.9m.**

This modification is valid wherever applicable in the step-by-step test procedure in Sec.6-9-2.

6.9.1 Requirements

EIDA R-703: *The PIs and the Prime Contractor shall ensure that on ground, at the location of the RPW-SCM, the overall AC magnetic field emitted by the spacecraft and the external environment, when measured with a 1Hz bandwidth, shall be at least 6dB below the red line in figure (Figure 9.1-1) below. Frequency stable narrow band spikes up to but not exceeding the red line are permitted, but the frequency space they occupy shall be less than 10% of the respective frequency decade (1Hz to 10Hz, 10Hz to 100Hz, etc.).*
D: Verification method: test.
D: Definition of “frequency stable”: The short term stability of potential narrow band emission lines will be better than 10E-5 for a period of 1 hour.
D: Goal is less than 1% per decade occupied by spikes across the full spectrum.

EIDA R-704: *The PIs and the Prime Contractor shall ensure that in flight at the location of the RPW SCM, the emitted AC magnetic field shall be below the black line in the figure (Figure 9.1-1) below when measured with bandwidths specified in requirement EIDA R-705. Frequency stable narrow band spikes up to but not exceeding the red line are permitted in accordance with Requirement EIDA R-703.*
D: *Verification method: Analysis by the Prime Contractor, using test results from EIDA R-705*

EIDA R-705: *The Prime Contractor, for the purposes of verification of requirement EIDA R-704, shall ensure that units will be tested for their AC magnetic field emissions with the following frequency bandwidths:*

- *1 Hz to 128 Hz: 0.125 Hz bandwidth*
- *128 Hz to 2048 Hz: 2Hz bandwidth*
- *2048 Hz to 12288 Hz: 12Hz bandwidth*
- *12288 Hz to 200 kHz: 122Hz bandwidth*
- *200 kHz to 1.002 MHz: 21kHz bandwidth*

D: *Verification method: test*
D: *AC magnetic characterization will be carried out at unit level by testing at close proximity to the unit (typically less than 1 m). The results will be combined to provide an analytical verification of EIDA R-704.*
D: *The physical location of the equipment on the spacecraft will be taken into account to derive the pass/fail criterion for requirement EIDA R-704, scaled to unit level. For this, the black and red lines of the figure below (Figure 9.1-1) may be scaled according to the distance between the unit under test and the location of the RPW-SCM using a factor of 1/r2.*

EIDA R-783: *The characterization tests shall have sensitivity such that the levels defined by the black line in Figure 9.1-1 are achieved. The distance at which the measurements are taken shall be scaled using a square law by reference to the distance between the locations of the unit and the SCM. Distances are given in Table 9.1-3.*

EIDA R-784: *The PI shall measure the radiated H-field emissions of each unit at the time of internal switching transients that will occur during normal operation, excluding switch-on/off and redundancy switching.*
D: *Measurement distance will be defined on a case by case basis. The test set-up shall be photographed in each configuration used.*

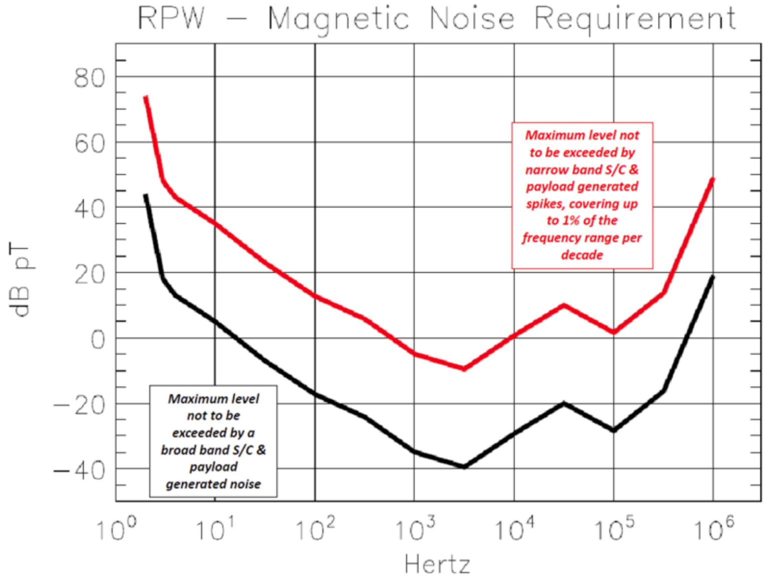


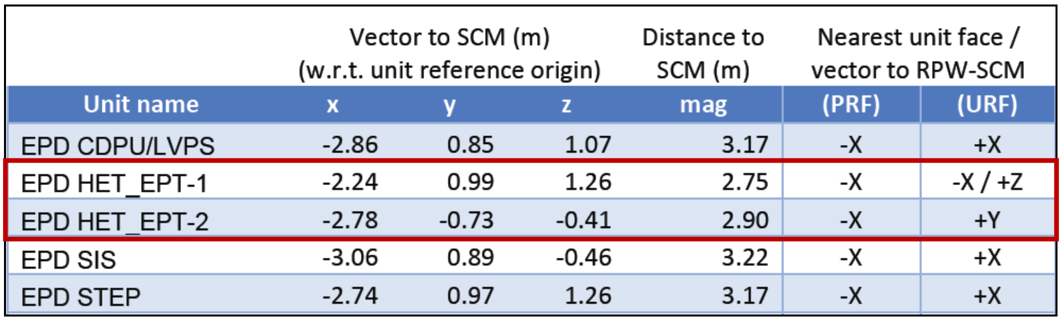
Fig. 6-9-1. Background noise at RPW-SCM, B^{min}_{noise}(black), and (B^{min}_{noise}+30 db) (red), **Ref: Fig. 9.1-1 of [AD-1].**

Table 6-9-1: Broadband noise at RPW-SCM, **Ref: Table 9.1-2 of [AD-1].**

Frequency (Hz)	Noise level (dB pT)
2	44
3	18
4	13
10	5
31.6	-7.0
100	-17.2
316.2	-24.2
1000	-34.9
3162.3	-39.5
1.0E4	-29.3
3.16E4	-20
1.0E5	-28.4
3.16E5	-16.3
1.0E6	19.0

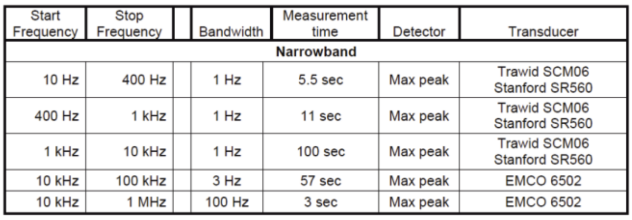
Note: Table 3 of [AD-3] is used because it has updated information compared to the Table 9-1-3 of [AD-1] regarding the position of EPD sensors.

Table 6-9-2: Distances between EPTHET1&2 and RPW-SCM, **Ref: Table 3 of [AD-3].**



	Vector to SCM (m) (w.r.t. unit reference origin)			Distance to SCM (m)	Nearest unit face / vector to RPW-SCM	
Unit name	x	y	z	mag	(PRF)	(URF)
EPD CDPU/LVPS	-2.86	0.85	1.07	3.17	-X	+X
EPD HET_EPT-1	-2.24	0.99	1.26	2.75	-X	-X / +Z
EPD HET_EPT-2	-2.78	-0.73	-0.41	2.90	-X	+Y
EPD SIS	-3.06	0.89	-0.46	3.22	-X	+X
EPD STEP	-2.74	0.97	1.26	3.17	-X	+X

Table 6-9-3: List of H-field frequency bands, band widths and magnetic sensor utilization, **Ref: Table 4 of [AD-3].**



Start Frequency	Stop Frequency		Bandwidth	Measurement time	Detector	Transducer
Narrowband						
10 Hz	400 Hz		1 Hz	5.5 sec	Max peak	Trawid SCM06 Stanford SR560
400 Hz	1 kHz		1 Hz	11 sec	Max peak	Trawid SCM06 Stanford SR560
1 kHz	10 kHz		1 Hz	100 sec	Max peak	Trawid SCM06 Stanford SR560
10 kHz	100 kHz		3 Hz	57 sec	Max peak	EMCO 6502
10 kHz	1 MHz		100 Hz	3 sec	Max peak	EMCO 6502

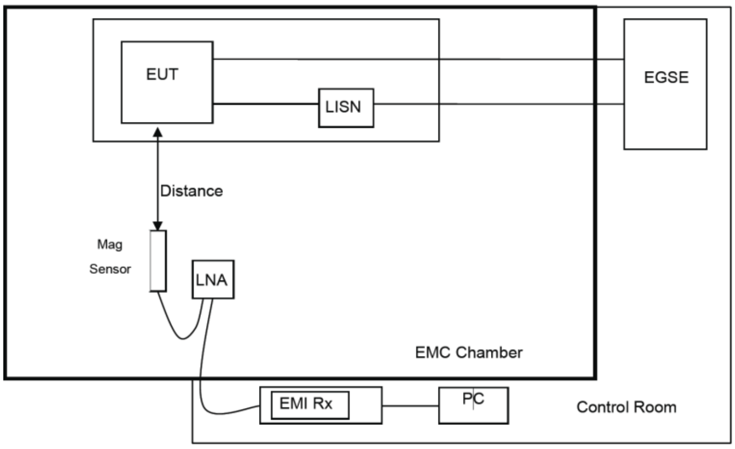


Fig. 6-9-2. H-field characterization set up with magnetic sensor 10Hz to 10 kHz, **Ref: Fig. 3-5 of [AD-3].**

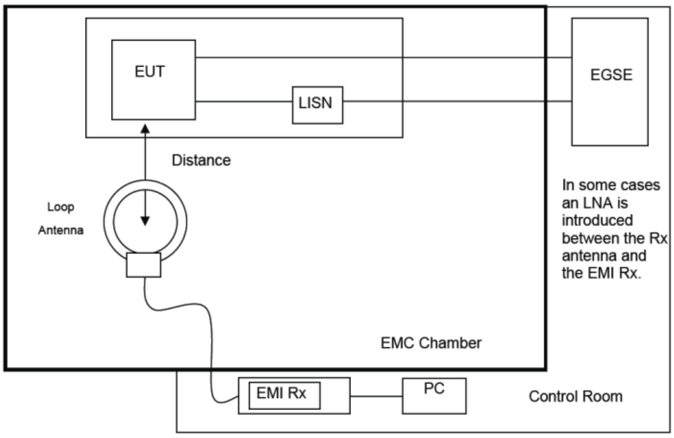


Fig. 6-9-3. H-field characterization set up using loop antenna for 10 kHz to 1 MHz, **Ref: Fig. 3-6 of [AD-3].**

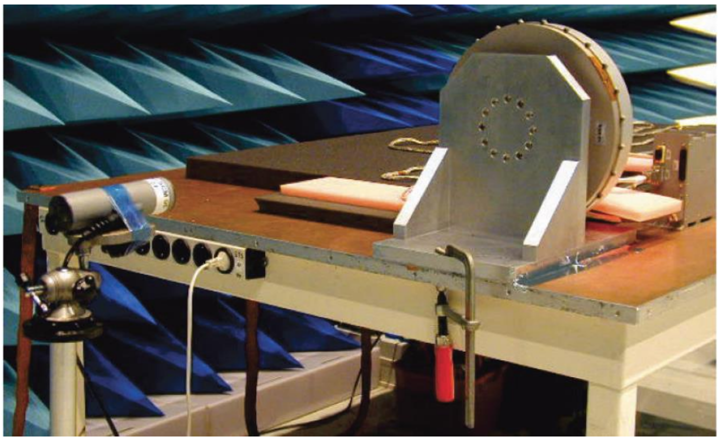


Fig. 6-9-4. H-field with Mag sensor Z-position 1 meter, **Ref: Fig. 3-7 of [AD-3].**

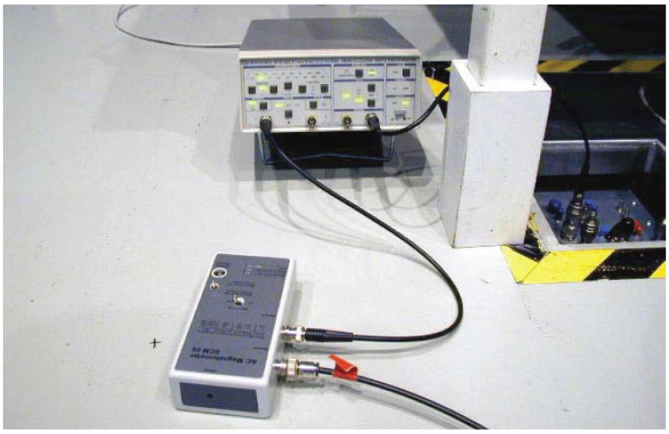


Fig. 6-9-5. H-field sensor LNA (Low Noise Amplifier), **Ref: Fig. 3-8 of [AD-3].**

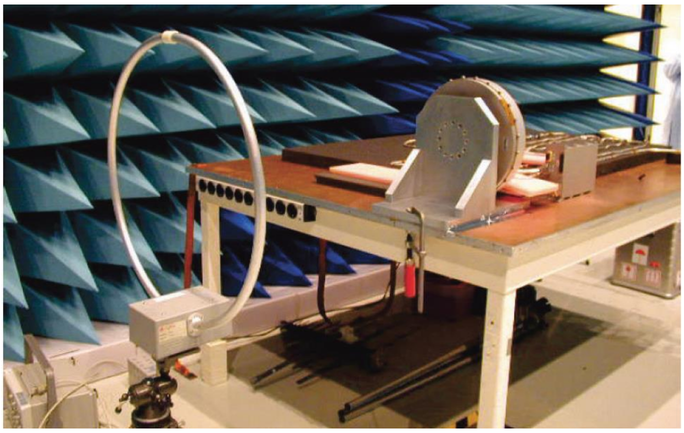


Fig. 6-9-6. H-field with loop antenna Z-position 1 meter, **Ref: Fig. 3-9 of [AD-3].**

Fig. 6-9-7. Scaled H-filed requirement limit for EPTHET-1 FM: **2.75m** separation from RPW-SCM, **1m** measurement distance.

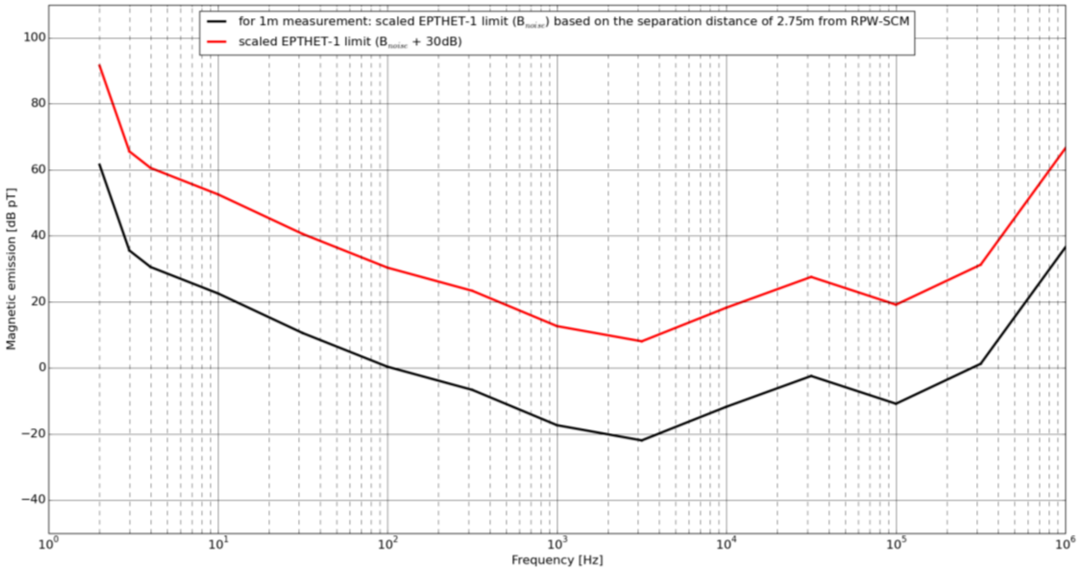
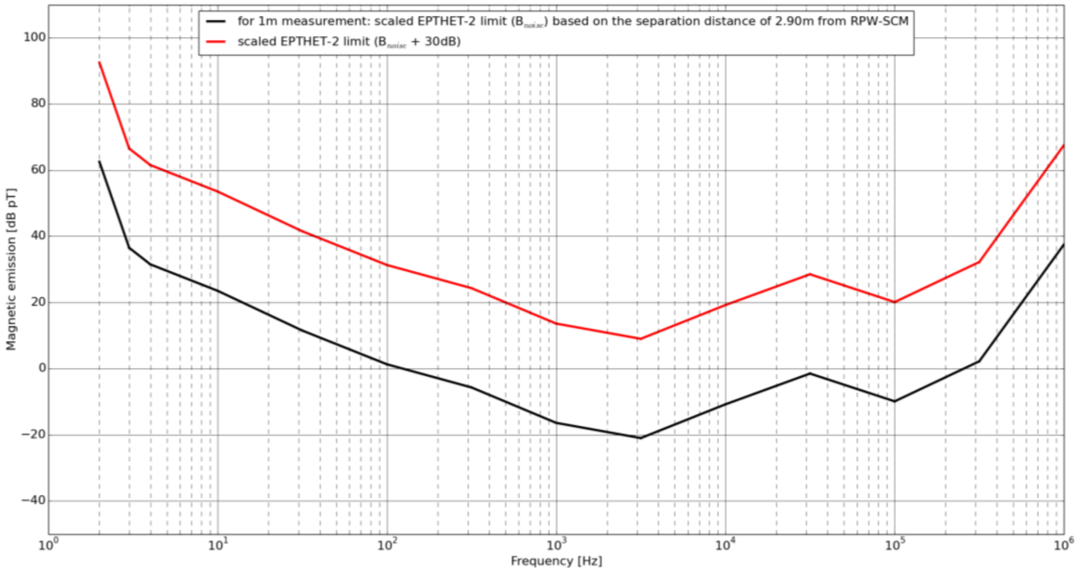


Fig. 6-9-8. Scaled H-filed requirement limit for EPTHET-2 PFM: **2.90m** separation from RPW-SCM, **1m** measurement distance.



6.9.2 H-field characterization step-by-step test procedure, Ref: Section 3.4.6 to 3.4.10 of [AD-3]

Step	Description	Date/time	Sign	Comment
00	**Bonding testing** Bonding testing should be performed again according to section 6.1. As a minimum, the following bonding points should be measured and recorded : 1)Equipment Bonding Stud to nearby structure grounding (limit <2.5 mOhms) In the event that a bonding stud is not provided (e.g. a tapped hole or mounting feet expected to be used) then the unit will be bonded to the Test Bench in a manner representative of the spacecraft installation and the measurements taken accordingly. 2) Equipment Bonding Stud to connector(s) housing (limit <10 mOhms) The bonding should be measured using a 4 wire bonding meter which passes a test current of greater than 0.1 A. The bonding should be also be measured with the probes connected in both one direction and then the reverse direction. The results should be recorded for each measurement made.			
05	**Equipment set up** The EUT and EMC test equipment should be set as shown in the **Fig. 6-9-2** (magnetometer measurements) and **Fig. 6-9-3** (loop antenna measurements) using the suggested test equipment listed in **Table 6-8-2.**			
10	**Ambient test procedure** **NOTE** As this Characterization testing is being performed at the sensitivity limits of the test facility and its test equipment it is important to make an initial			

Step	Description	Date/time	Sign	Comment
	measurement of the ambient electromagnetic conditions i.e. with the EGSE ON and the EUT OFF to ensure the contribution from the EGSE is known. It may well be necessary to adjust the layout and bonding positions of harnesses etc. to ensure the set-up in the chamber closely replicates the final spacecraft installation. Some experimentation with the EMI test equipment grounding and cable locations may also be necessary in order to minimize the ambient noise seen by the test receiver. Locate the magnetic probe at a distance of 1m from the EUT face closest to the in-flight representative location of the RPW-SCM instrument. If the unit reference frame is aligned in the same direction with the spacecraft reference frame this is most likely the –X face of the EUT. However, for each unit the correct face can be determined from the vector between the unit and the location of RPW-SCM given in **Table 6-9-2**, when combined with a transformation from the spacecraft co-ordinate frame into the unit reference frame. To ensure that measurements are taken from the correct face in the unit reference frame, the right most column of **Table 6-9-2** indicates the unit face closest to the RPW-SCM instrument in the unit reference frame (URF). Take similar photographs of the test set-up **Fig. 6-9-4 to Fig. 6-9-6.**			
15	**Ambient 1 (only Z-axis of sensor)** With the Magnetic probe set into its ‘X’ orientation, the EUT OFF and the EGSE ON, set the receiver to scan from 10 Hz to 400 Hz using the bandwidths and measurement times specified in **Table 6-9-3**. Record the results in amplitude (dBpT) versus frequency plot.			

Step	Description	Date/time	Sign	Comment
	Repeat the measurements for the frequency bands 400 Hz to 1 kHz and record and plot the results. Repeat the measurements for the frequency bands 1kHz to 10 kHz and record and plot the results. At 10 kHz stop the scan and change the antenna for the loop antenna as shown in **Fig. 6-9-3** which is orientated to measure the ‘X’ orientation. Take a photograph and measure and record the emissions from the 10 kHz to 100 kHz and the 100 kHz to 1 MHz bands.			
20	**H-field EUT ON test procedure** Locate the magnetic probe at a distance of 1m from the EUT face closest to the representative in-flight location of the RPW-SCM instrument (see **Table 6-9-2**, **Fig. 6-9-2** and **Fig. 6-9-3**). Take similar photographs to the ones shown in **Fig. 6-9-4** to **Fig. 6-9-6** of the test set-up.			
25	**Test 1 (Z-axis of sensor and 1 m distance from EPTHET-1 [-X] face in URF or EPTHET-2 [+Y] face in URF)** • For **1m** measurement limit is as seen in Fig.6-9-7 or . Fig.6-9-8. With the magnetic probe set into its ‘Z’ orientation, the EUT ON and the EGSE ON, set the receiver to scan from 10 Hz to 400 Hz using the bandwidths and measurement times specified in **Table 6-9-3**. Record the results in an amplitude (dBpT) versus frequency plot. Repeat the measurements for the frequency bands 400 Hz to 1 kHz and record and plot the results. Repeat the measurements for the frequency bands 1kHz to 10 kHz and			

Step	Description	Date/time	Sign	Comment
	record and plot the results. At 10 kHz stop the scan and change the magnetic probe for the loop antenna as shown in **Fig. 6-9-3** which is orientated to measure the 'X' orientation. Take a photograph and measure and record the emissions from the 10 kHz to 100 kHz and the 100 kHz to 1 MHz bands.			
30	**Test 2 (Z-axis of sensor and 1 m distance from EPTHET-1 [-X] face in URF or EPTHET-2 [+Y] face in URF)** • For **2.75m (EPTHET-1) and 2.90m (EPTHET-2)** measurements limit are the same and as seen in Fig.6-9-1 With the magnetic probe set into its 'Z' orientation, the EUT ON and the EGSE ON, set the receiver to scan from 10 Hz to 400 Hz using the bandwidths and measurement times specified in **Table 6-9-3**. Record the results in amplitude (dBpT) versus frequency plot. Repeat the measurements for the frequency bands 400 Hz to 1 kHz and record and plot the results. Repeat the measurements for the frequency bands 1kHz to 10 kHz and record and plot the results. At 10 kHz stop the scan and change the magnetic probe for the loop antenna as shown in **Fig. 6-9-3** which is orientated to measure the 'X' orientation. Take a photograph and measure and record the emissions from the 10 kHz			

Step	Description	Date/time	Sign	Comment
	to 100 kHz and the 100 kHz to 1 MHz bands.			
35	**Calculation of limit line for each equipment under test** Calculate the specific limit guide line for the EUT. To do this, take the original limit guideline in **Fig. 6-9-1** and relax it by adding the following field in dBpT as follows: $\mathit{Specific\ limit\ guide\ line} = \mathit{Original\ limit\ guide\ line} + 40 \log_{10}\left(\frac{d_{separation}}{d_{measurement}}\right)$ Where ***d**separation* is the separation distance between the EUT and the SCM flight instrument and can be obtained using the reference table in **Table 6-9-2.** • For **1m** measurement limit is as seen in Fig.6-9-7 and Fig.6-9-8. • For **2.75m (EPTHET-1) and 2.90m (EPTHET-2)** measurements limit are the same and as seen in Fig.6-9-1			
40	**Determination of acceptability of test results** If there are no peaks present that exceed 6 dB below the specific limit guide line, no further testing is required. If there are peaks present within 6 dB below the specific limit guide line or that exceed the limit line, identify the peaks and note the values of the most significant peaks.			
45	All the results should be provided in a standard Microsoft EXCEL file format, such as CSV, to enable subsequent combination and data processing of the results.			
50	Test conclusion			

6.10 DC magnetic properties and demagnetization

6.10.1 Requirements

After the DC magnetic properties measurement, demagnetization will be performed on EPTHET-1 FM and EPTHET-2 PFM according to EIDA R-773.

EIDA R-796: *The PI shall ensure that maximum magnetic moment of each instrument unit on the spacecraft complies with the table below (Table 4.10-1):*

Table 6-10-1: DC magnetic field allocations per instrument, **Ref: Table 4.10-1 of [AD-1].**

Unit	Maximum permitted magnetic dipole (mAm^2)	Maximum permitted dynamic DC magnetic field measured at 1m (nT)	Maximum permitted periodic transient measured at 1m (pT)
EPTHET- 1	10	18	110
EPTHET-2	10	30	170

EIDA R-680: *The Prime Contractor shall ensure that the DC magnetic field at the location of the outboard magnetometer sensor is lower than 20 nT.*
D: *In order to meet scientific objectives fully, the magnetic field should be below 10 nT.*
D: *The maximum allowed magnetic moments for instrument units contributing to the magnetic field at the location of the magnetometer outboard sensor are defined EIDA R-796.*

EIDA R-681: *The PIs and Prime Contractor shall ensure that during EMC quiet periods, the only spacecraft-generated magnetic fields at the location of the outboard magnetometer sensor, on timescales between 1/64s and 1s, are:*
· Transients as defined below, superimposed to the DC value (which is limited by R-680) with maximum peak-to-peak amplitude of 1 nT.
· Field variations of amplitude less than 10 pT.
D: *Magnetic field transients are defined as non-periodic variations of the magnetic field with a duration of less than a second and an amplitude above 10 pT (TBC). This includes step-functions.*

EIDA R-682: *The PIs and Prime Contractor shall ensure that magnetic field transients happening during EMC quiet phases are time-tagged and reported in TM. Their sources shall be identified.*
D: *Where a pre-defined sequence causes a series of transients it is only necessary to provide telemetry of the start of the sequence and the list of events within that sequence.*
D: *The precision of the timing shall be of 1s or better.*

EIDA R-842: *The PIs shall ensure that the only instrument-generated magnetic fields at a distance of 1 metre from the corresponding unit on time scales between 1/64 s and 1 s are:*
· Transients with maximum peak-to-peak amplitude specified in the table associated with R-796 (Table 4.10-1).
· Field variations of amplitude less than specified in the table associated with R-796 (Table 4.10-1).

EIDA R-773: *The PI shall conduct demagnetisation at the level of 5 mT of every unit as part of the DC magnetic testing performed prior to delivery. In case that a unit is not suitable for demagnetisation, the PI shall inform ESA and the Prime and agree an alternate test approach.*

6.10.2 DC magnetic properties measurement step-by-step test procedure, Ref: Section 5.4.5 of [NR-09]

Step	Description	Date/time	Sign	Comment
00	**Set up** The EUT should be set in an earth field compensated area providing zero-field conditions for the intrinsic moment determination. **NOTE** • This is necessary in case the EUT contains a significant amount of soft magnetic material, as without earth field compensation an induced magnetic moment would appear. • Earth field compensation is usually ensured by 2 or 3 sets of Helmholtz coils.			
05	A right-handed orthogonal coordinate system XYZ shall be assigned to the EUT geometric center.			
10	The magnetic sensor (single-axis magnetometer) shall be installed successively on the 6 semi-axes at two different reference distances r1 and r2 from the geometric center of the EUT and shall measure the field projection along these lines. **NOTE** The reference distances are typically more than three times the size of the EUT.			
15	Alternatively the EUT may be installed on a turntable and rotated in front of a fixed magnetometer, presenting each XYZ axis (positive and negative) successively aligned with the sensor axis.			
20	The magnetic field shall be positive when orientated from the center of the EUT towards the magnetometer.			
25	**Test sequence**			

Step	Description	Date/time	Sign	Comment
	EUT not operating, initial measurements on the six semi-axes at the reference distances.			
30	**Deperm: Ref: Fig. 5-12 of [NR-09].** EUT not operating, application of a deperming field in accordance with Figure 5-12 frequency 3 Hz, maximum amplitude between 4000 µT and 5000 µT, successively on each XYZ axis of the EUT. **NOTE** • This is usually done using Helmholtz coils. • A sequence of symmetrical sine periods of increasing and decreasing amplitude gives better results than a sine wave modulated by exponentials or ramp functions. Measurement after deperm on the six semi-axes at the reference distances.			
35	**Perm:** EUT not operating, application of a perm field of 300 µT on each XYZ axis. Measurement after perm on the six semi-axes at the reference distances.			
40	Stray field: EUT operating, measurement on the six semi-axes at the reference distances. **NOTE** The DC magnetic properties transient are measurement in scales 1/64 and 1 s. Recommendations from [AD-7] to be considered.			
45	**Final Deperm:** Repeat Deperm according to Step 30.			
50	**Data presentation** For each measurement distance, for each of the 6 semi-axes, the following induction measurements in µT are plotted in tabular form: *B*(+X), *B*(-X), *B*(+Y), *B*(-Y), *B*(+Z), *B*(-Z)			

Step	Description	Date/time	Sign	Comment
	For each measurement distance, mean inductions, for each axis, are computed in units of µT and plotted in tabular form, using following equations: $B_X = \frac{B_{(+X)} - B_{(-X)}}{2}$, $B_Y = \frac{B_{(+Y)} - B_{(-Y)}}{2}$, $B_Z = \frac{B_{(+Z)} - B_{(-Z)}}{2}$ For each measurement distance r, 3-axes magnetic moment components in units of Am^2 are calculated using the following equations and reported: Mx = 5 r3 BX M in units of Am^2, r in meters, B in µT My = 5 r3 BY Mz = 5 r3 BZ Using values of Mx, My and Mz at both distances r1 and r2, values M1 and M2 of the magnetic moment are calculated using the following equations and reported: $M_1 = \sqrt{M_x(r_1)^2 + M_y(r_1)^2 + M_z(r_1)^2}$ $M_2 = \sqrt{M_x(r_2)^2 + M_y(r_2)^2 + M_z(r_2)^2}$ **NOTE** If the EUT is a centred dipolar source, then M1 = M2.			