Title: **EMC Test Plan**

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1 INTRODUCTION

This plan provides the baseline for EMC testing on HERSCHEL payload modules and satellite.

The plan is based on the HERSCHEL AIT planning as reflected in the Satellite AIT Plan (ref. [AD1]) and the general verification philosophy provided in the PLM EMC Control and Verification Plan, [AD3].

It describes the hardware levels applicable for EMC testing under ASED responsibility, the test flow as well as the tests which are required.

Based on this test plan, the EMC detailed test procedures shall be written.

2 DOCUMENTS

For the EMC test plan the following documents are applicable:

[AD1]	Satellite AIT Plan (part 2)	HP-2-ASED-PL-0026
[AD2]	HERSCHEL GDIR	H-P-1-ASPI-SP-0027
[AD3]	HERSCHEL EMC Specification	H-P-1-ASPI-SP-0037
[AD4]	EMC Control and Verification Plan	HP-2-ASED-PL-0013
[AD5]	HERSCHEL PLM AIV Grounding Diagram	HP-2-ASED-DW-0002
[AD6]	HERSCHEL/PLANCK Frequency Plans	H-P-1-ASPI-PL-0201

The following documents has been referred to:

[RD1]	EMC/Power Working Group Meeting 17	
[RD2]	Changes to H/P EMC Specification	HP-ASP-CR-0417
[RD3]	Spire EQM Test Plan	SPIRE-RAL-DOC-001905

3 HERSCHEL EMC TEST PHILOSOPHY

3.1 Objective

EMC qualification will be achieved by EMC tests foreseen on EQM as well as on PFM hardware.

We have to distinguish between the PLM EQM equipped with the modified CVV of ISO, the PLM PFM and the complete spacecraft PFM.

An overview about the different tests foreseen with respect to the above mentioned test models is given in table 3.1-1 below.

All EMC test except the bonding and grounding measurements shall be done under COLD conditions in order to be flight representative.

§ EMC Spec	EMC Spec	Subject	PLM EQM	PLM PFM	S/C PFM
3.2.3.2.1	EMCPLM-000	CE Narrow Band Current on primary power lines towards PCDU measured with Spectrum Analyser Common Mode. See also [RD1]	--	T	T
3.2.3.2.1	EMCPLM-010	CE Common and Differential mode on pre-amps and detector power lines (secondary power). See [RD2]	--	--	--
3.2.4.8.4	EMCEQ-500	CS DM Continuous. See [RD1].	--	--	--
3.2.4.8.4	EMCEQ-520	CS CM Continuous. See [RD1].	--	--	--
3.2.4.8.4	EMCEQ-550	CS DM Transient. See [RD1].	--	--	--
3.2.4.8.4	EMCEQ-560	CS DM Transient. See [RD1].	--	--	--
3.2.4.8.4	EMCEQ-570	CS CM Transient. See [RD1].	--	--	--
3.2.3.2.3	EMCPLM-030	RS test	T	--	--
3.2.2.3	EMCSYS-92	CE Common and Differential Mode and noise tests on power lines between PCDU and instruments	--	--	T
3.2.2.3	EMCSYS-096	CE on TBD links between the SVM and PLM	--	--	T
3.2.2.3	EMCSYS-098	Voltage ripple between SVM and PLM structure	--	--	T
3.2.2.1.1	EMCSYS050	RE E-field Narrowband in VEB plane in Launch Mode	--	--	T
3.2.2.1.1	EMCSYS-052	RE E-field Narrowband at UHF and C-band in Launch Mode	--	--	T
3.2.2.1.2	EMCSYS-60	RE E-field Narrowband in Operational Mode at 3 points around the cryostat from 14 kHz - 18 GHz	--	--	T
3.2.4.6.2.1	EMCEQ-200	RS E-field	--	--	T
3.2.4.6.2.2	EMCEQ-250	RS H-field AC	--	--	T

Table 3.1-1: EMC Tests Overview

3.2 Tests on HERSCHEL PLM EQM Configuration

Tests in this configuration will be performed in a standard integration facility (no anechoic chamber).

In order to be allowed to perform the RS test outside the anechoic chamber the radio regulation community have formally to be requested for permission at least 6 months prior to test.

CE and CS tests on primary power side are not foreseen because of limited representativity of the AVM primary power interfaces and the unavailability of the PCDU. Instead, for the CE/CS performance of the instruments it shall be referred to the instruments test programmes of PACS, SPIRE and HIFI.

CE/CS tests on secondary power and on cryo harness are not foreseen. The HIFI requested CE/CS tests on cryoharness will not be performed because 1. the quite low emission level making the CS test unfeasible and 2. because a RS test is foreseen anyway.

3.3 Tests on HERSCHEL PLM PFM Configuration

For EMC tests in this configuration a standard integration facility is sufficient. For the tests the SVM with the PCDU is necessary. The test shall therefore be conducted in frame of the SVM integration with the PLM PFM and will therefore formally done on satellite level.

3.4 Tests in Fully Integrated Satellite PFM Configuration

In this configuration CE (as far as not already done representative on PLM PFM configuration), Launcher RS/RE as well as the autocompatibility test will be performed. All tests will be performed in the integration facility except RE/RS tests which will be tested in the anechoic chamber. The feasibility to perform the CE measurements in this configuration is still TBC. The only possibility would be to test CE during the integration phase of the satellite. In this case the representativity of the test result may be questionable.

4 HERSCHEL OVERALL EMC TEST PROGRAMME

4.1 General

The objective of the EMC test programme is to demonstrate that the design is in accordance with the EMC requirements. The particular EMC requirements will be summarised in a separate chapter in this document.

During the test programme it shall be verified that the PLM and the HERSCHEL satellite is:

- compliant with the Launcher requirements
- compliant with the satellite requirements and in particular
- self compatible

4.2 Test Sequence

Under consideration of the different configurations the EMC test programme comprises the main test blocks in a sequential order as shown in figure 4.2-1 and figure 4.2-2 below.

Based on the test descriptions provided in this plan, 6 kinds of test procedures will be written:

- Mechanical and electrical integration procedures
- PLM EQM EMC test procedure
- PLM PFM EMC test procedure
- HERSCHEL PFM CE test procedure
- HERSCHEL PFM Radiated Test Procedure
- HERSCHEL Autocompatibility Test Procedure

The content of these procedures will be in line with the test planning and testing amount as defined in this test plan.

The mentioned test blocks will be embedded into the overall test sequence considering the applicable PLM modes and instruments operationability. For the PLM the EMC test sequence will be proposed in the present test plan. The test sequence for the PLM PFM and the satellite level shall be defined later, based on the experiences gained from the EQM programme.

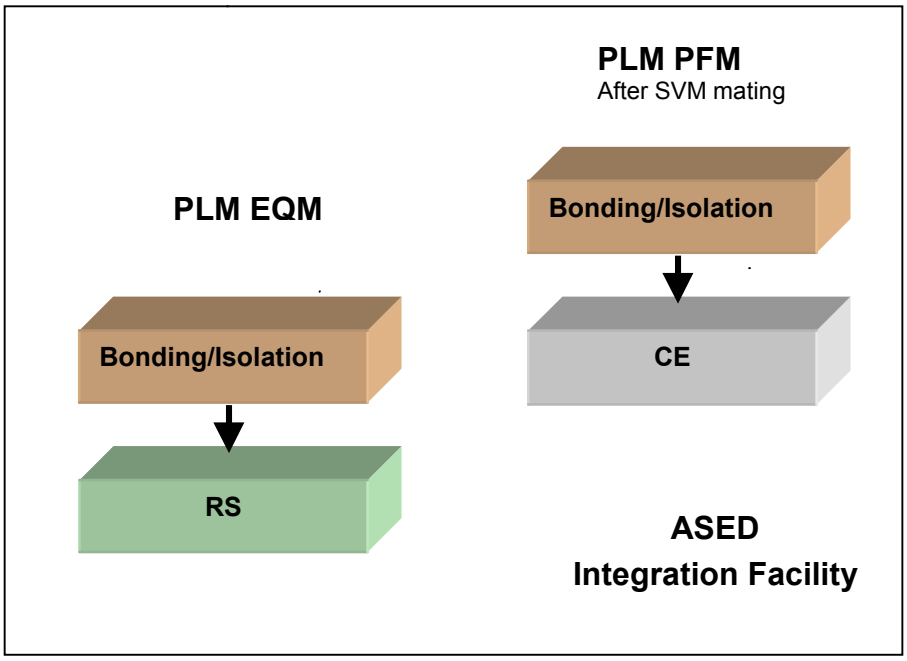

Fig. 4.2-1: PLM EMC Test Blocks

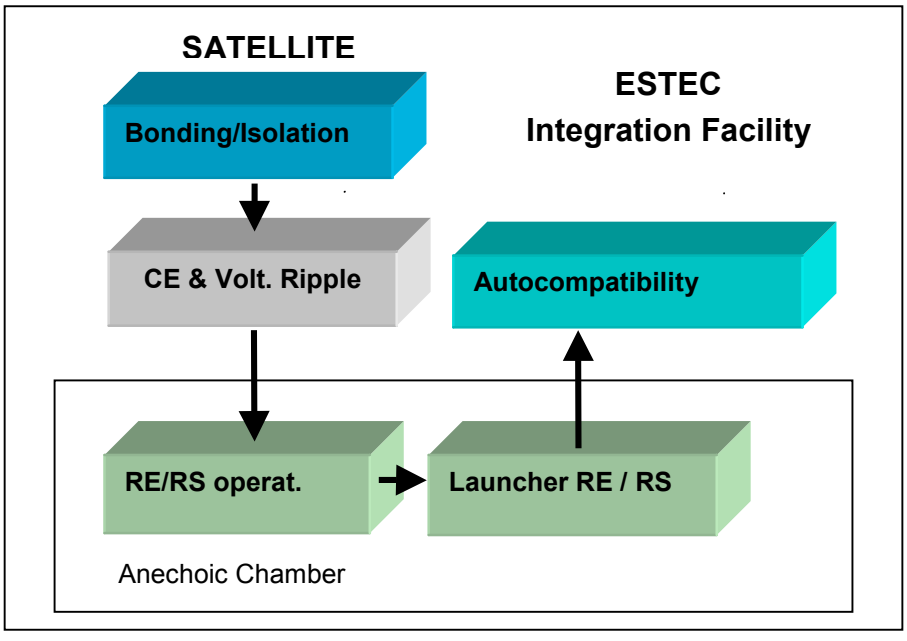

Fig. 4.2-2: Satellite EMC Test Blocks

4.2.1 PLM EQM EMC Test Sequence

R1: HIFI ON, PACS STB, SPIRE STB

Reference test , MODE TBD by HIFI

RS, sensitive MODE acc. to § 5.1.1.1, quicklook capability TBD by HIFI, Performance data storage with reference to RS injection event/frequency: Capability to be checked: TBD by HIFI

Refer also to para 5.1.1.1.

R2: PACS ON, HIFI STB, SPIRE STB

Cooler recycle

Reference test , MODE TBD by PACS

RS, sensitive MODE TBD by PACS, quicklook capability TBD by PACS, Performance data storage with reference to RS injection event/frequency: Capability to be checked: TBD by PACS.

Refer also to para 5.1.1.2.

R3: SPIRE ON, HIFI STB, PACS STB

Cooler recycle (2h) every 24 h

Reference test , MODE TBD by SPIRE

RS, sensitive MODE TBD by SPIRE, EMI detection by Spire Quick-Look-Analysis (QLA), Performance data storage with reference to RS injection event/frequency: Capability to be checked: TBD by SPIRE

Detector sampling frequency to be set to the maximum (around 80 Hz).

Refer also to para 5.1.1.3.

4.2.2 PLM PFM EMC Test Sequence

TBD.

4.2.3 Satellite EMC Test Sequence

TBD. The satellite test sequence shall consider the lessons learnt from PLM test sequence.

4.3 Applicable EMC Requirements for PLM

The EMC requirements as applicable for HERSCHEL are shown in the EMC requirements specification, [AD2]. Bonding, grounding isolation requirements shall be retrieved from the GDIR, [AD2]. The relevant requirements for the PLM (EQM and PFM), are summarised below.

4.3.1 Bonding/Isolation

For the various Bonding/Isolation requirements it shall be referred to the GDIR, [AD2]. The conductance of those tests shall be covered by integration procedures, i.e. mechanical integration procedures.

4.3.2 PLM Conducted Emission

4.3.2.1 Requirement

Conducted emission shall be measured on to be selected signal lines between the SVM and the PLM. **Detailed requirements, lines to be tested and test methods are TBD by ASPI.**

4.3.2.2 Operation

All equipment shall be operated in their nominal modes inclusive the most emissive modes.

4.3.2.3 Configuration

The PLM EQM is connected to the SVM Simulator fully loaded with the avionics modules, whereas the PLM PFM will be used with the SVM FM.

The CVV will be connected to the Helium pumping units via large tubes. For a limited time these units might be switched OFF, the mechanical connection however cannot be cut.

The use of break-out boxes shall be limited because they allow the facility generated noise to enter the equipment

4.3.3 PLM Conducted Susceptibility

N/A

4.3.4 PLM Radiated Susceptibility

4.3.4.1 Requirements

- ***The RS E-field*** levels as required shall not lead to malfunction:

2 V/m in the frequency range from 14 kHz to 18 GHz

10 V/m and 18 V/m in particular notches

The sine wave signal shall be 30% amplitude modulated by 1 kHz squarewave. Above 30 MHz the requirement shall be met both for horizontal and vertical polarization. The test shall be performed as per MIL 462 RS03.

- ***The RS H-field*** level of 140 dBpT in the frequency range from 30 Hz to 50 kHz shall not lead to malfunction.

Above tests are required for the EQM PLM only and not for the PFM PLM. At least 3 frequencies per decade shall be tested. The instruments have to define a table of relevant frequencies prior to test. 3 antenna positions shall be used for the RS E-field as well for the RS H-field test.

4.3.4.2 Operation

For the RS tests the PLM shall be in operational mode. In any case the equipment shall be operated to be sensitive.

Performance checks shall be performed as usual. In case of susceptibility, the susceptibility threshold shall be predicted. The details for the prediction of the susceptibility threshold shall be clarified with the manufacturer of the equipment which has failed.

4.3.4.3 Configuration

The RS test will be performed in the standard integration facility. In order to minimize interferences from neighbored facility, the clearance between the PLM and the facility shall be at least 2 m (see also figure 4.3.4.3-1 below). As far as possible absorber walls shall be installed, at least however at the opposite side of the radiating antenna as well as behind the antenna in order to minimize effects of standing waves.

The PLM EQM will be equipped with the SVM Simulator fully loaded with the avionics modules, whereas the PLM PFM will be used with the SVM FM.

The CVV will be connected to the Helium pumping units via large tubes. For a limited time these units might be switched OFF, the mechanical connection however cannot be cut.

The use of break-out boxes is not permitted because they would allow the RS noise to enter the equipment.

The wiring between the PLM and the EGSE shall be specifically shielded with Al foil (to be integrated before start of test).

The test antennas shall be placed at TBD positions directed to the PLM openings and the harness.

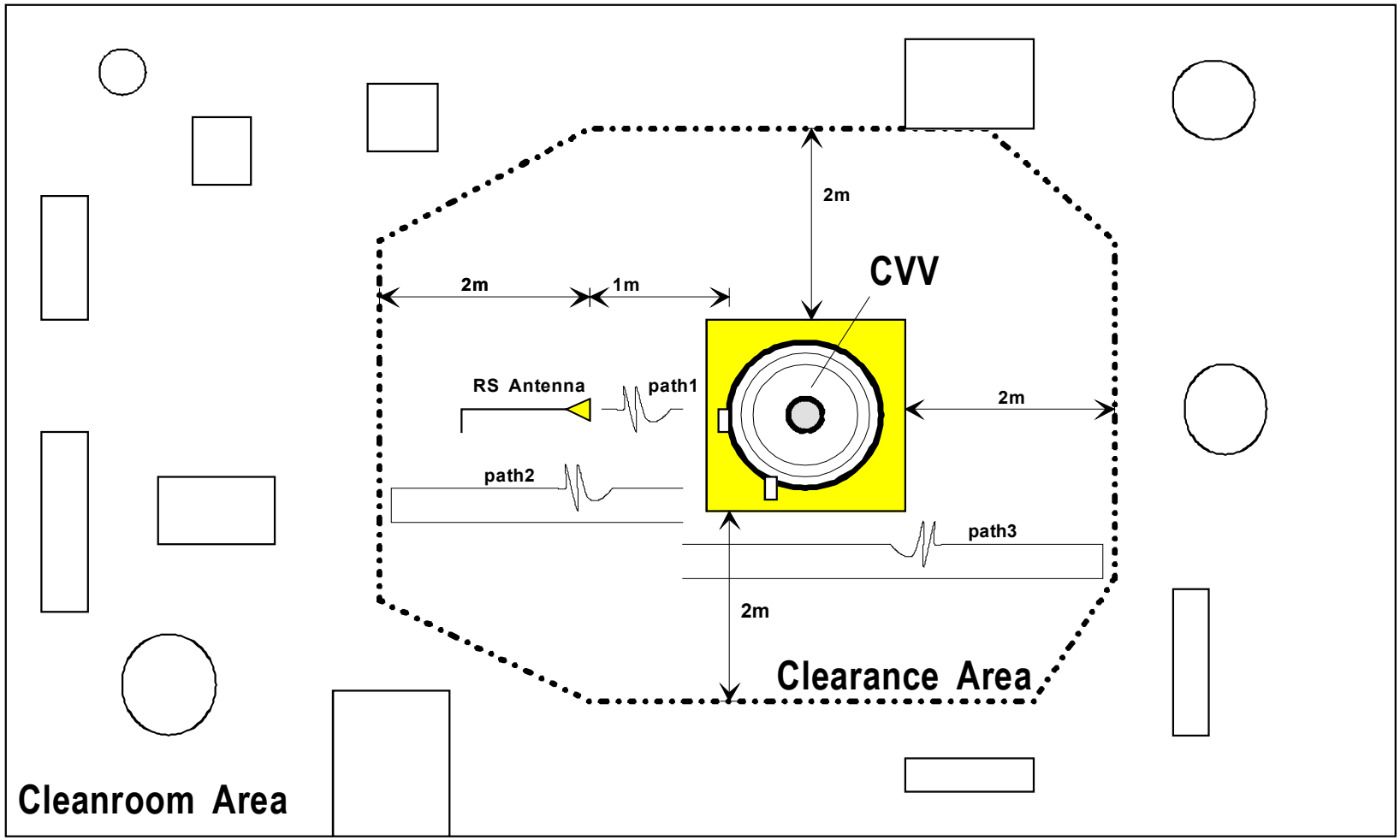

Fig. 4.3.4.3-1: Configuration of the PLM Within the Integration Facility during the RS Test

4.4 Applicable EMC Requirements for HERSCHEL Satellite (S/C PFM)

The EMC requirements as applicable for HERSCHEL are shown in the EMC requirements specification, [AD2]. Bonding, grounding isolation requirements shall be retrieved from the GDIR, [AD2]. In the following, the requirements relevant for the HERSCHEL satellite, are summarised below.

4.4.1 Bonding/Isolation

For the various Bonding/Isolation requirements it shall be referred to the GDIR, [AD2]. The conductance of those tests shall be covered by integration procedures, i.e. mechanical integration procedures.

4.4.2 Spacecraft Conducted Emission

4.4.2.1 Requirements

- On each primary power lines from the PCDU to the instruments warm unit spectral analysis of common and differential mode current shall be performed in the frequency range from 30 Hz to 50 MHz. Details TBD
- On each primary power lines from the PCDU to the instruments warm unit RMS noise measurement shall be performed on a 10 MHz frequency bandwidth (measured with RMS voltmeter or digital oscilloscope capable to compute it). Details TBD
- CE measurements on TBD links between service module and payload module shall be performed.
- The voltage ripple between SVM and PLM structures shall be measured.

Remark: The TBDs shall be clarified by ASPI

4.4.2.2 Operation

All equipment shall be operated in their nominal modes inclusive the most power consuming modes.

4.4.2.3 Configuration

Integrated Satellite configuration without outer MLI, TBD

The PCDU will be powered with the solar array simulator unit in order to provide for best representativity.

The CVV will be connected to the Helium pumping units via large tubes. For a limited time these units might be switched OFF, the mechanical connection however cannot be cut.

The use of break-out boxes shall be limited because they allow the facility generated noise to enter the equipment. Spacecraft antennas shall be covered with test caps which can handle the amount of radiated power.

4.4.3 Spacecraft Radiated Emission

4.4.3.1 Requirement

- In Launch mode the RE-E-field shall not exceed the figure below as measured at VEB plane.
- In operational mode the E-field shall be measured from 3 different locations around the cryostat in the frequency range from 14 kHz to 18 GHz.

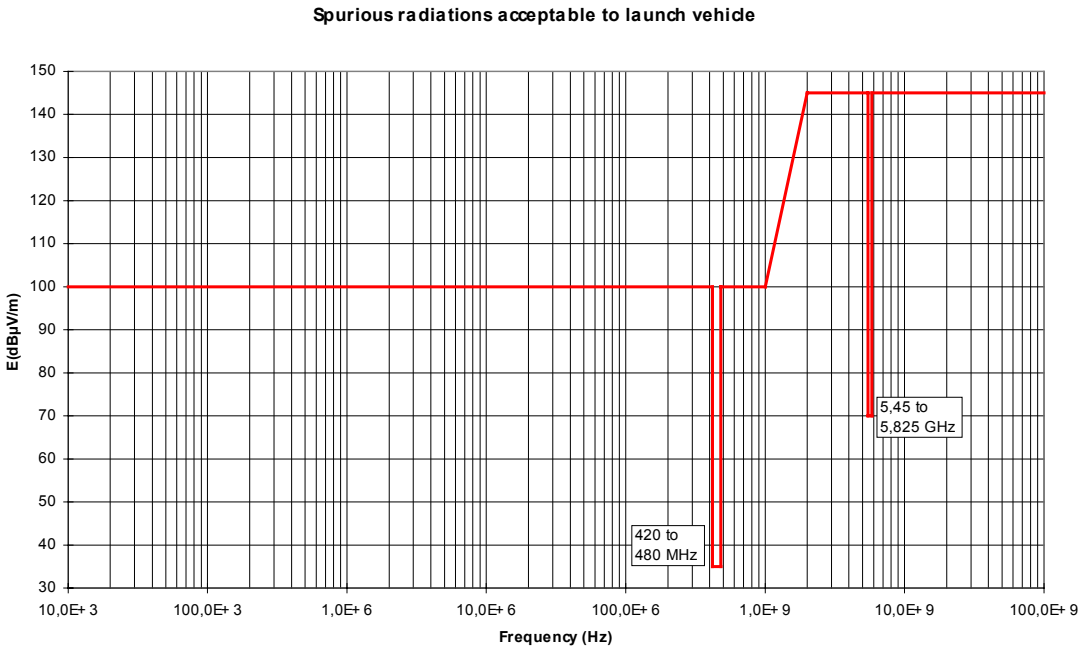

Fig.4.4.3.1-1: Maximum tolerable E-field in Launch Mode

4.4.3.2 Operation

All equipment shall be operated in their nominal modes inclusive the most power consuming modes. In Launch mode the measurement shall be made once the satellite is powered by the solar array simulator power supply (prelaunch) and when powered by internal battery (launch mode). When powered by the battery the test duration must not exceed 2 hours (TBC).

Remark: Battery Management TBD by ASPI

4.4.3.3 Configuration

The test shall be performed in the anechoic chamber: The test antennas shall be placed at 1 m distance and shall aim at 3 positions directed to harness and optical apertures of the cryostat for the operational mode. For the Launch mode 1 position is sufficient to be directed to the spacecraft separation interface. The positions shall be proposed in the corresponding test procedures.

The on-board antennas shall be covered with test caps in order to limit the radiation at TX frequency. The test caps shall be capable to handle the TX power without constraints. The wiring between the satellite and the EGSE shall be specifically shielded with Al foil (to be integrated before start of test).

The CVV will be connected to the Helium pumping units via large tubes. For a limited time these units might be switched OFF, the mechanical connection however cannot be cut.

4.4.4 Spacecraft Radiated Susceptibility

4.4.4.1 Requirements

- The RS E-field levels as required shall not lead to malfunction:

  2 V/m in the frequency range from 14 kHz to 18 GHz

  10 V/m and 18 V/m in particular notches

  The sine wave signal shall be 30% amplitude modulated by 1 kHz squarewave. Above 30 MHz the requirement shall be met both for horizontal and vertical polarization. The test shall be performed as per MIL 462 RS03.
- The RS H-field level of 140 dBpT in the frequency range from 30 Hz to 50 kHz shall not lead to malfunction.

4.4.4.2 Operation

For the RS E-field test the satellite shall be tested both in operational as well as in launch mode. For RS H-field only operational mode shall be tested. In any case the equipment shall be operated to be sensitive.

Performance checks shall be performed as usual. In case of susceptibility, the susceptibility threshold have to be predicted. The details for the prediction of the susceptibility threshold shall be clarified with the manufacturer of the equipment which has failed.

4.4.4.3 Configuration

The test shall be performed in the anechoic chamber: The test antennas shall be placed at 1 m distance and shall aim at 3 positions directed to harness and optical apertures of the cryostat for the operational mode. For the Launch mode 1 position is sufficient to be directed to the separation interface. The positions shall be proposed in the corresponding test procedures.

The on-board antennas shall be covered with test caps in order to limit the radiation via on-board antennas at TX frequency. The test caps shall be capable to handle the TX power without constraints. It shall be checked if the venting holes of the test caps are suitable not to let the RS fields penetrating to the inside. In any case of question they shall be closed e.g. by aluminised adhesive foil The wiring between the satellite and the EGSE shall be specifically shielded with Al foil (to be integrated before start of test).

The CVV will be connected to the Helium pumping units via large tubes. For a limited time these units might be switched OFF, the mechanical connection however cannot be cut.

4.4.5 Satellite Autocompatibility

Autocompatibility of the satellite shall be demonstrated by this test

4.4.5.1 Operation

In general the operational mode of the satellite with its RF instruments shall allow a fully flight representative operation of the equipment.

During the test the performance checks shall be performed as usual for susceptibility tests. In case of susceptibility, possible disturbance sources shall be switched-off, one after another, to identify the source of the disturbance. Moreover the susceptibility threshold have to be predicted.

The details for the prediction of the susceptibility threshold shall be clarified with the manufacturer of the equipment which has failed.

4.4.5.2 Configuration

The test of the fully assembled satellite (inclusive MLI) shall can be performed either in a standard integration facility or in the aneqhoic chamber just after the EMC test campaign. The antenna shall be covered by a test cap in order to be able for commanding and telemetry reception of the TT&C subsystem.

The CVV will be connected to the Helium pumping units via large tubes. For a limited time these units might be switched OFF, the mechanical connection however cannot be cut.

5 GENERAL SET-UP

5.1 Satellite Set-up

5.1.1 Satellite Mode

For emissive tests (CE, and RE), the satellite must be set up to generate the maximum amount of noise, whereas for the susceptibility tests (RS), it have to be in the most sensitive mode possible.

5.1.1.1 HIFI Modes

The (draft) proposed HIFI settings for emission as well as for susceptibility testing are:

Mode:	Normal mode
Band:	3 a
Frequency (LO):	840 GHz TBC
HRS mode:	High resolution
HRS band center frequency:	7.2 GHz TBC
WBS:	ON
Observing mode:	Total Power
Integration Time:	1 sec (shortest possible time allowed by transfer speed /ICU)
Chopper:	Cold Load

For susceptibility testing the EMI shall be synchronized with integration packets to make pairs at the same EMI frequency one packet measured with the EMI on the other a reference with the EMI off..

Prior to and after the actual EMI test we would need to do a calibration of the instrument with the EMI off. The details of this calibration are **TBD by HIFI**.

5.1.1.2 SPIRE Modes

Refer to [RD3]

5.1.1.3 PACS Modes

TBD by PACS: To be clarified by PACS

5.1.2 Performance Verification

Prior to the start of the EMC test programme the satellite will have been subjected to the full functional tests. As a result, a high degree of confidence will exist with respect to its proper performance.

A functional check (reference test) shall be performed prior the conducted and the radiated EMC test sequences for the purpose of a health check. A reference test is not required after the EMC test campaign since proper operation is verified throughout the EMC tests, in much more detail than the information provided by the reference test. Therefore functional checks should be clearly distinguished

from performance evaluation of equipment during RS tests, during which the performance is investigated in detail. Therefore the RS test forms the end of the EMC test campaign.

5.1.3 Built Status

The built status w.r.t. EMC representativity, as well as the built status of the instruments used in the HERSCHEL test campaign, is addressed in the test readiness review (TRR).

5.1.4 Susceptibility Criteria

A susceptible condition may be defined as a malfunction, unintentional mode change or degradation of performance occurring during application of the susceptibility test signal.

5.1.4.1 HIFI Criteria

Fail/Pass criteria are **TBD by HIFI.** To be clarified by HIFI.

5.1.4.2 SPIRE Criteria

Refer to [RD2]

5.1.4.3 PACS Criteria

Fail/Pass criteria are **TBD by PACS**. To be clarified by PACS.

5.1.5 Satellite Operating Constraints

5.1.5.1 HK Sampling Rate (TBC by ASPI)

The Satellite HK data is sampled on-board every 1 second but transmitted only every 4 seconds. Therefore, instead of continuous sweeping step-wise frequency adjustment shall be considered for susceptibility testing. A minimum exposure time of 8 seconds is recommended for each RS frequency step. The HK and transmission sampling rate could be increased to 1 Hz for single parameters, on the expense of the number of parameters which can be monitored. Therefore, an increase of the sampling rate may be considered only for specially selected parameters, based on unit level test results, e. g. where susceptibility was found. (which parameters are in the baseline to be monitored, what is the granularity of the frequency steps)

To clearly identify if HK parameters are affected during susceptibility tests, more stringent monitoring limits than used in flight may be considered for these tests.

The HK data is transmitted from HERSCHEL via the data front end to the core EGSE for data monitoring and evaluation.

The H/K parameters checked during susceptibility testing will be listed in the test procedures.

5.2 Ground supports set-up

5.2.1 Test sites

All tests on PLM will be performed in the cleanroom of Astrium facilities. Satellite level testing is foreseen at ESTEC facilities. For conducted tests a standard integration facility is sufficient. The autocompatibility test can be performed einter in the anechoic chamber or in the integration area. Radiated emission and susceptibility tests must be performed in the anechoic chamber. The anechoic chamber of ESTEC have to be prepared to allow testing under clean room conditions.

5.2.2 GSE

A schematic of all EGSE/MGSE used for satellite level testing is given in the AIV Grounding Diagram, [AD04]. For more details it may be referred to the respective design descriptions and users manuals. A detailed list of all EGSE used for the various configurations shall be given in the respective TRR.

5.2.3 Software

As discussed before, the various test sequences will command HERSCHEL into noise generating or sensitive modes. The S/C will be operated during EMC testing in a flight representative manner, i.e. the flight OBSW and the Test S/W as defined for the functional tests can be used with the following exceptions:

Monitoring limits may have to be modified for radiated susceptibility tests (OBSW and Test SW).

5.2.3.1 Reference Test

For the definition of the reference test objectives it shall be referred to the System Test Plan

5.2.3.2 Emission test mode

A dedicated sequence shall be used during conducted and radiated emission tests. This sequence has to command to noise generating modes. Hence this mode should comprise

- powering of equipment
- commanding of equipment into most noisiest mode
- HK data monitoring

This will be covered by nominally used AP’s combined to a sequence as required.

5.2.3.3 Susceptibility test mode

Another dedicated sequence shall be used during susceptibility (radiated) tests. This sequence has to command the satellite to sensitive modes. Hence this mode should comprise

- powering of equipment
- commanding of equipment into most sensitive mode
- application of instrument stimuli if necessary (to be clarified)

- transmission and distribution of the scientific data to the various instrument EGSE for further analysis and evaluation.
- HK data monitoring

This will be covered by nominally used AP's combined to a sequence as required.

6 TEAM ORGANISATION

Test conductance will be performed by the HERSCHEL EMC responsible. HERSCHEL operation personnel will be participating as required.

For tests at ASED, test engineering will be performed by ASED EMC facility personnel.

For tests at ESTEC facilities, test engineering will be performed by ESTEC EMC facility personnel.

The customer is invited to witness the tests as desired.

DISTRIBUTION

	Name	Dep./Comp.		Name	Dep./Comp.
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	Huber Johann	ED 543		Wagner Adalbert	OTN/IP 35
	Hund Walter	SE 76		Wagner Klaus	SM 31
X	Idler Siegmund	ED 432		Wietbrock, Walter	ED 521
	Iványi von András	ACE 32		Wöhler Hans	SM 34
	Jahn Gerd Dr.	SM 31		Zipf Ludwig	ACE 32
X	Kalde Clemens	ED 532			
x	Kameter Rudolf	OTN/EN 64			
	Kersting Stefan	OTN/EN 63	X	Alcatel	ASPI
	Kettner Bernhard	SM 34	X	ESA/ESTEC	ESA
X	Knoblauch August	ED 531			
x	Koelle Markus	ED 533		**Instruments:**	
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	Peters, Gerhard	ED 531		Linde	LIND
	Pietroboni Karin	ED 65		Patria New Technologies Oy	PANT
	Puttlitz Joachim	OTN/EN 64		Phoenix, Volkmarsen	PHOE
	Raupp Helmut	SM 33		Rembe, Brilon	REMB
	Rebholz Reinhold	ED 541		SENER Ingenieria SA	SEN
	Reuß Friedhelm	ED 62			