SPIRE

SUBJECT: **SPIRE EMC Control Plan**

PREPARED BY: **Douglas Griffin**

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Change Record

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0.1	7 September 2001	1st Draft issued internally for comments
0.2	2 February 2002	Updated distribution Reference to the REM (Radiated EMC Model) removed

Notes

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GLOSSARY

ADP	Acceptance Data Package
AVM	Avionics Model
BDA	Bolometer Detector Array
BSM	Beam Steering Mirror
CE	Conducted Emission
CM	Common Mode
CMRR	Common mode rejection ratio
CQM	Cryogenic Qualification Model
CS	Conducted Susceptibility
CVV	Cryostat Vacuum Vessel
DM	Differential Mode
DPU	Digital Processing Unit
DRCU	Detector Readout and Control Unit
EEE	Electronic, Electrical and Electromechanical components
EQM	Electronic Qualification Model (see footnote on page 9 regarding ambiguity in terminology)
ESA	European Space Agency
ESD	Electrostatic Discharge
EUT	Equipment Under Test
FPGA	Field Programmable Gate Array
FPU	Focal Plane Unit
FS	Flight Spare
FTS	Fourier Transform Spectrometer
HCDMU	Herschel Command and Data Management Unit
HPDU	Herschel Power Distribution Unit
ISO	Infrared Space Observatory (the predecessor mission to Herschel)
JFP	The photometer JFET unit
JFS	The spectrometer JFET unit
LCL	Latching Current Limiter
LIA	Lock-In Amplifier
LISN	Line Impedance Stabilization Network
LOU	Local Oscillator Unit (a component of the HIFI instrument mounted outside the flight cryostat)
LWS	Long Wave Spectrometer (one of the ISO instruments)
NA	Not applicable
P/LW	Long wave photometer
P/MW	Medium wave photometer
P/SW	Short wave photometer
PC	Prime Contractor
PFM	Proto-Flight Model
RAL	Rutherford and Appleton Laboratory
RE	Radiated Emission
REM	Radiated EMC Model
RF	Radio Frequency
RO	Responsible Organization
RS	Radiated Susceptibility

RTU	Remote Terminal Unit
S/C	Spacecraft
S/LW	Long wave spectrometer
S/SW	Short wave spectrometer
SCU	300-mK Sorption Cooler Unit
SMEC	Spectrometer Mechanism
SPIRE	Spectral and Photometric Imaging Receiver
SSICD	Subsystem Interface Control Document
STM	Structural Thermal Model
TBC	To be confirmed
TBD	To be decided
TBW	To Be Written
WE	Warm Electronics (which consists of the DRCU, DPU and WIH)
WIH	Warm Interconnect Harness
ZPD	Zero Path Difference (in reference to the FTS)

APPLICABLE DOCUMENTS

This document incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at appropriate places in the text and publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these apply to this document only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

AD1	FIRST/Plank IID-A		
AD2	SPIRE Instrument Development Plan	SPIRE-RAL-PRJ-000035	
AD3	SPIRE AIV Plan,	SPIRE-RAL-000410	
AD4	SPIRE IID-B		
AD5	Herschel SPIRE Detector Subsystem Specification Document	SPIRE-JPL-PRJ-00045	Version 1.9

REFERENCE DOCUMENTS

The following documents, although not a part of this EMC control plan, amplify or clarify its contents:

RD1	Herschel/Plank Instrument Interface Document – Part B for SPIRE, SPIRE-ESA-DOC-000275
RD2	SPIRE HARNESS DEFINITION SPIRE-RAL-PRJ-000608
RD3	SPIRE EMC Test Procedures, SPIRE-RAL-PRJ-(TBW)
RD3	Cooler ICD
RD4	ECSS-E-20A Space Engineering, Electrical and Electronic
RD5	SPIRE Instrument Qualification Requirements, SPIRE-RAL-PRJ-000592
RD6	SPIRE Grounding and Screening Philosophy, SPIRE-RAL-PRJ-00624

1. INTRODUCTION

1.1 Purpose

It is the intention of this document to explain the satellite payload, instrument and the sub-system level programme of EMC testing of the SPIRE instrument. These tests are intended to ensure the correct operation of the instrument under flight conditions with the presence of expected EM disturbances and to ensure that the instrument does not create an intolerable disturbance to itself or the other Herschel systems and instruments. In doing this, the document describes how the specific requirements set out in the Herschel/Plank IID-A and the SPIRE IID-B are met.

The tests will be carried out by the subsystem providers for unit level tests, RAL for instrument level tests and under the control of the Herschel/Plank prime contractor for satellite payload level tests.

1.2 Scope

The scope of the plan is intended to cover the EMC control of the following items of flight hardware:

1. the FPU and all subsystems enclosed within it,
2. the JFET units (JFS and JFP),
3. the DRCU, (DCU and FCU)
4. the DPU, and
5. all instrument cold and warm harnesses.

Included in the scope are issued related to ESD immunity and testing.

The verification of the instrument EMC requirements by test, and design at instrument and subsystem level is described.

Microphonic disturbances to the instrument, although related to EMC and signal quality, are not within the scope of this document. Similarly, the effects on the performance and long term stability of SPIRE under the effects of cosmic radiation fall outside the scope of this document.

The design of the EGSE for EMC compatibility is not covered here. It is assumed however, that the EGSE will adequately match the electrical characteristics of the spacecraft to ensure the validity of the tests outlined below.

1.3 Summary of SPIRE model philosophy

In the development of the SPIRE instrument, six models have been identified in AD 2. These models are briefly described in Table 1-1. For a more complete description of the various models, see AD 3.

Table 1-1 - SPIRE deliverable model philosophy

Model Designation	Name	Description
AVM	Avionics Model	SPIRE EGSE that is intended to electrically mimic the operation of the FPU and the DRCU along with a DPU that is equivalent to the flight DPU but not made from flight qualified components
STM	Structural-Thermal Model	A mechanically representative model of the instrument without electrical functionality but including correct electrical dissipation.
CQM	Cryogenic Qualification Model	A flight representative model of the FPU, JFS and JFP (with potentially fewer active pixels)
EQM[1]	Electronics Qualification Model	A flight representative model of the WE to allow for unit qualification (Conducted EMI and EMI susceptibility, Thermal-vac and Warm Vibration)
QM1/QM2	Qualification Model	These are models of the warm electronic units used for qualification.
PFM	Proto-flight model	The fully qualified model intended for flight
FS	Flight Spare	A flight qualified model used for spares for the PFM

Several EMC tests on these models have already been identified in AD2 and AD3.

The abiding approach, common to all space projects in demonstrating compliance as early on in the development plan is adopted here. The satellite payload level testing on the PFM will be acceptance rather than qualification testing. See §4.6.1.2 for discussion of the practicalities of applying this approach to SPIRE.

1.4 Summary

A diagrammatic summary of the flow of the EMC control test and verification plan is illustrated in Figure 1-1. It can be seen from the outset that the intention is to plan for EMC compatibility of the instrument and instrument sub-systems in the design phase. After this, sub-system, system, instrument and satellite level testing will be carried out as shown to confirm that requirements have been met. The testing program seeks to verify that the EMC performance requirements have been met as early in the development program as possible so that the program and budgetary risks are minimized.

[1] The acronym EQM has also been adopted by Astrium to identify a refurbished EM of the ISO cryostat. Throughout this document, the acronym EQM is assumed to be defined as above and in AD 2. The tests carried out on the three Herschel instruments in the adapted ISO EM cryostat is nominated here as the Herschel Instrument CQM tests.

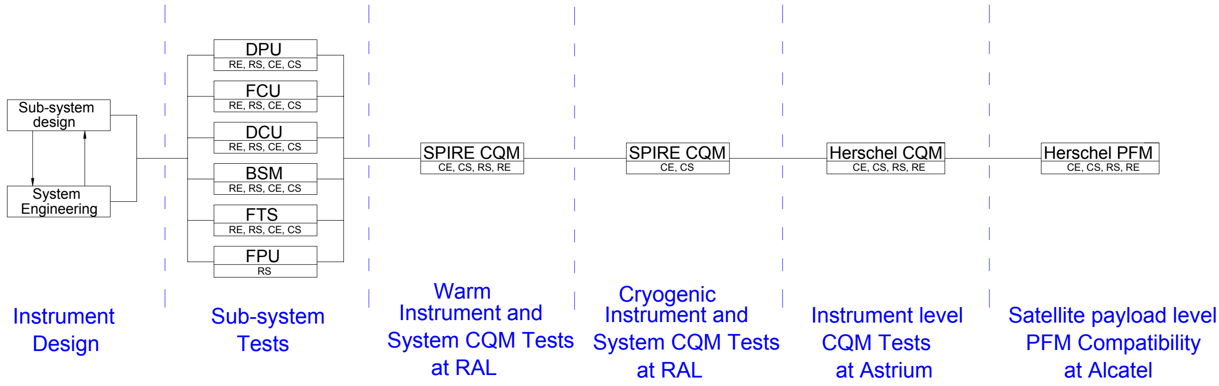

Figure 1-1 – Schematic representation of the EMC plan for SPIRE where CE indicates conducted emission tests, CS = conducted susceptibility, RE = radiated emissions and RS = radiated susceptibility.

No retest or hardware adjustments in the event of problems are indicated here. If needed, these will be planned for and conducted on a case-by-case basis.

2. EMC DESIGN GUIDELINES

The primary means of guaranteeing EMC of the SPIRE instrument is by adopting accepted good practice in the design phase of the instrument and the constituent subsystems. The guidelines outlined in AD1, §5.14 have been adopted in the design where possible. Any deviations from these guidelines will be highlighted in the Subsystem Design Description Documents with appropriate justifications for the design choice.

The criticality of the EMC design of the SPIRE instrument can be divided into two levels. The first level includes the design of the warm electronics on the SVM of the spacecraft (excluding the detector read out and biasing electronics). This design presents no unusual problems or challenges to the EMC of the overall instrument. This equipment must nonetheless operate within its operational specifications while meeting the required EMC specifications and must not generate intolerable disturbances to other systems.

The second level of EMC criticality lies in the cryogenic focal plane subsystems and the warm analogue detector read out and biasing electronics. For information purposes, the noise amplitude requirement for these signals referenced to the detectors is summarised below in Table 2-1. This information comes from AD5. The noise budget allocation for EMI signals referenced to the detector is less than 5nV/rtHz. Meeting these noise level specifications with around 5m of harnessing between the focal plane and the readout electronic in a potentially noisy RF environment is very difficult.

Table 2-1 – Detection subsystem noise budgets allocations (AD5).

	P/LW (nV/rtHz)	P/MW (nV/rtHz)	P/SW (nV/rtHz)	S/LW (nV/rtHz)	S/SW (nV/rtHz)
Photon	21	25	29	25	29
Phonon	9	9	9	9	9
Johnson	7	7	7	7	7
Load resistor	2	2	2	2	2
JFET	7	7	7	7	7
LIA	6	6	6	6	6
A/D	4	4	4	3	3
Quad. Subtotal	26	29	33	29	33
Thermal$^+$	< 6	< 7	< 8	< 12	< 11
EMI/EMC	< 5	< 5	< 5	< 5	< 5
Microphonic	< 5	< 5	< 5	< 5	< 5
Quad. Total	< 27	< 31	< 35	< 32	< 35

There are three components of the EMI noise budget for the detection and readout system:

(1) Conducted EMI inducing voltages in the detection and read out circuits.
(2) Radiated EMI inducing voltages and currents in the detection and readout circuits.
(3) Conducted and radiated EMI inducing currents across the bolometer elements and dissipating power within the detector element. As the detector element is a bolometric device, the heat produced by the dissipation will cause a temperature rise of the device and, in turn causes a spurious signal to be generated. Since the bolometers have such a high sensitivity ($2x10^8$V/W), this seemingly negligible noise source cannot be ignored.

The following provisions have been incorporated into the design of the critical detection and read out circuits in order to meet the EMI noise requirements laid out in AD5.

1. The FPU structure is designed to be an RF tight enclosure. All harnesses entering this enclosure are filtered with EMI three terminal capacitors passing through a bulkhead to ensure that high-frequency, conducted currents are not passed into the RF tight enclosure and act as transmission antennas within the FPU. This RF tight enclosure encompasses all hardware inside the FPU, the harnesses passing from the FPU to the JFS and JFP and the JFS and JFP enclosures themselves.
2. The grounding scheme of the detectors and detector readout circuits is implemented to render the system as insusceptible to EMI as is possible. In particular, the FPU, JFS and JFP RF tight enclosure are all electrically insulated from the S/C structure. This is because it is anticipated that the cryostat structure and the Herschel Optical Bench will be carrying EMI currents.
3. The components in the pre-amplification stage of the read out circuit have been selected to maximise the common mode rejection ratio to improve EMI immunity. This is important as one of the primary noise pick up sources will be by common mode in the signal harnesses between the JFS/JFP and the DCU.
4. JFETs have been used to lower the input impedance seen by the lock-in amplifiers. This is particularly important as there is approximately 7m of harness between the detectors and the warm electronics. Lowering the input impedance to the lock-in amplifiers will lower the susceptibility of the circuit to differential mode EMI pickup.
5. LIA amplifiers have been implemented to make the signal detection bandwidth as narrow as is practical and therefore reject out of band EMI signals.
6. The JFETs have been located as close to the detectors as is possible within the space and thermal constraints. This minimises the length of the highly susceptible, low signal amplitude, high source impedance detector-JFS/JFP harnesses. Currently the length of these harnesses is less than 0.5m.
7. The grounding scheme for the sensitive detection system is carefully analysed to determine which implementation will give the optimal performance.

A simplified drawing of the overall SPIRE grounding diagram is illustrated below in Figure 2-1.

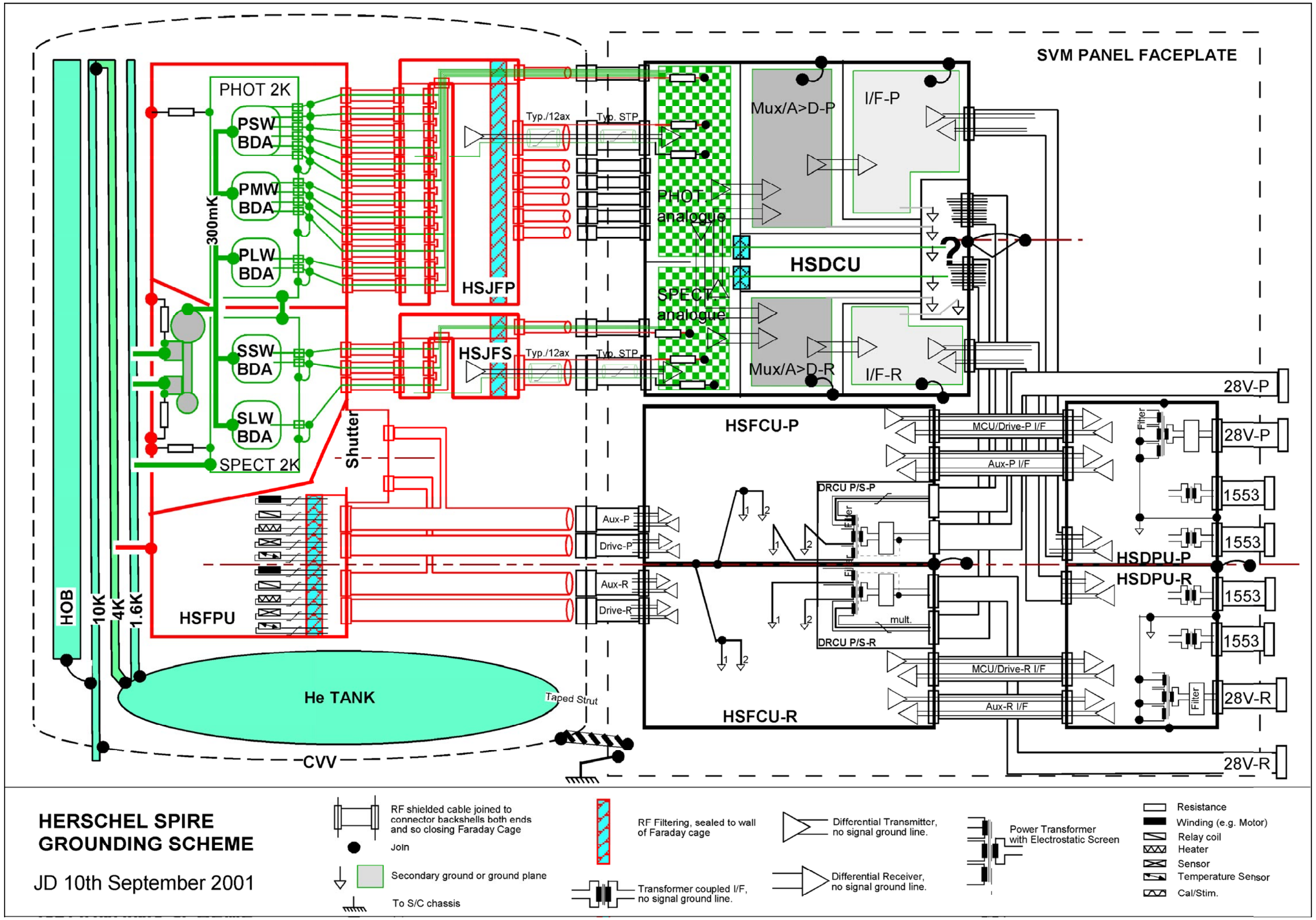

Figure 2-1 - Overall SPIRE grounding diagram.

3. EMC Design Analysis

The design process of SPIRE uses circuit-modelling software to evaluate design alternatives and conduct trade-off studies. In particular, the following issues have been evaluated with Orcad[2].

1. Detector readout grounding scheme
2. CVV EMI characteristics.

For both of these analyses, a model is required that reflects the actual behaviour of the detector at operating temperatures. The model is illustrated in Figure 3-1. The circuit relates the temperature of the detector by balancing the instantaneous flow of heat into the detector due to ohmic heating, external photon heating and the loss of heat into the detector substrate. The resistance of the detector is related to the temperature of the detector via the standard NTD thermistor resistance equation. Three external ports are connected to the detector circuit. **DetIn** and **DetOut** represent the two ports in the physical device. **PowerIn** represents the sum of the true optical and spurious power loading the device.

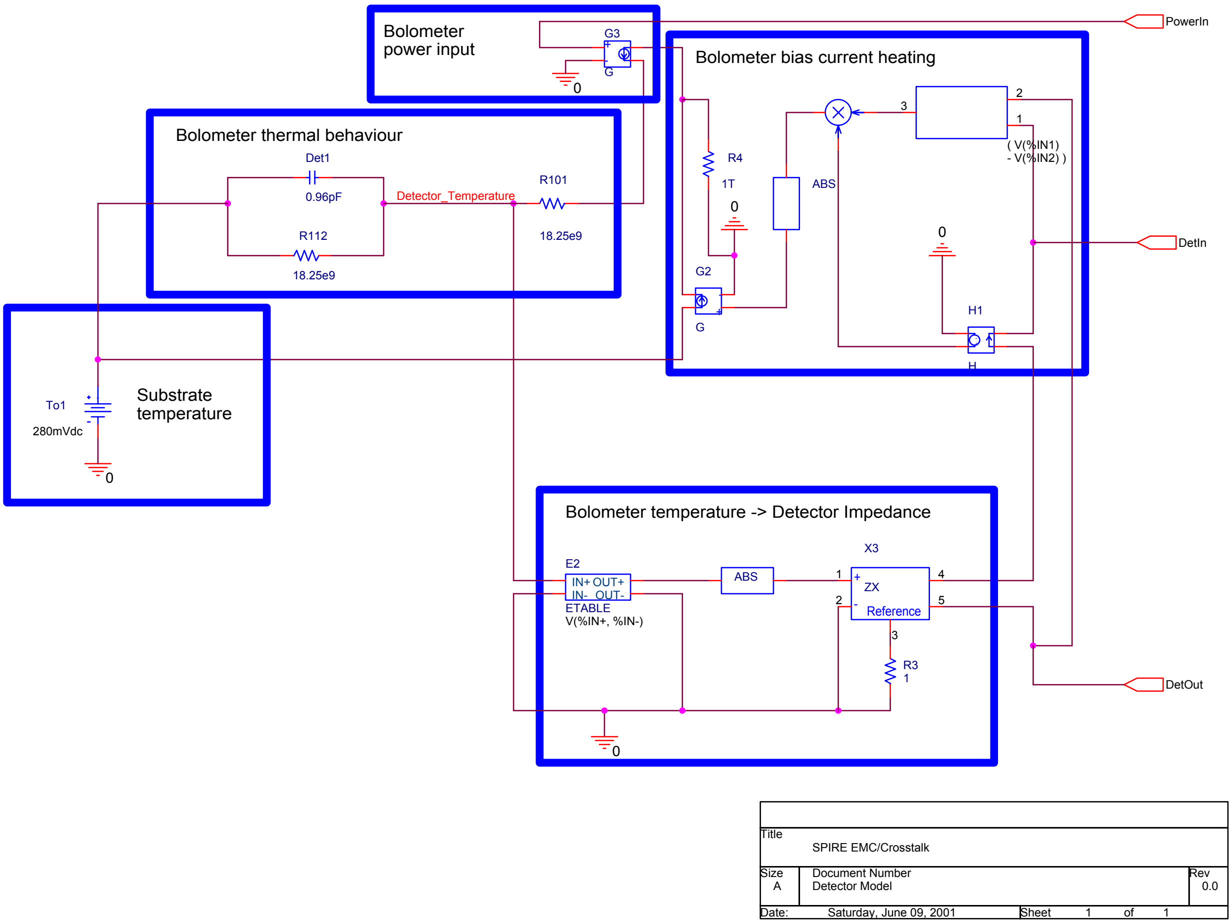

Figure 3-1 – Equivalent circuit of the SPIRE bolometric detector**.**

[2] Orcad is a commercial low frequency circuit analysis software package that uses SPICE as the core solver.

3.1 Detector readout grounding scheme

The proposed grounding scheme for the detection subsystem is shown in Figure 3-2. Each subsystem is electrically isolated from the spacecraft structure except for a single grounding point where the secondary ground. Figure 1-1 is a schematic representation of the grounding diagram of detection grounding scheme. There are two separately grounded systems; one for the photometer and one for the spectrometer. There are three possibilities for making the link to chassis. (a) at the 1.7K detector boxes, (b) in the warm DCU, and (c) at the EMC filter wall. The design analysis will be used to determine which of these is the most useable.

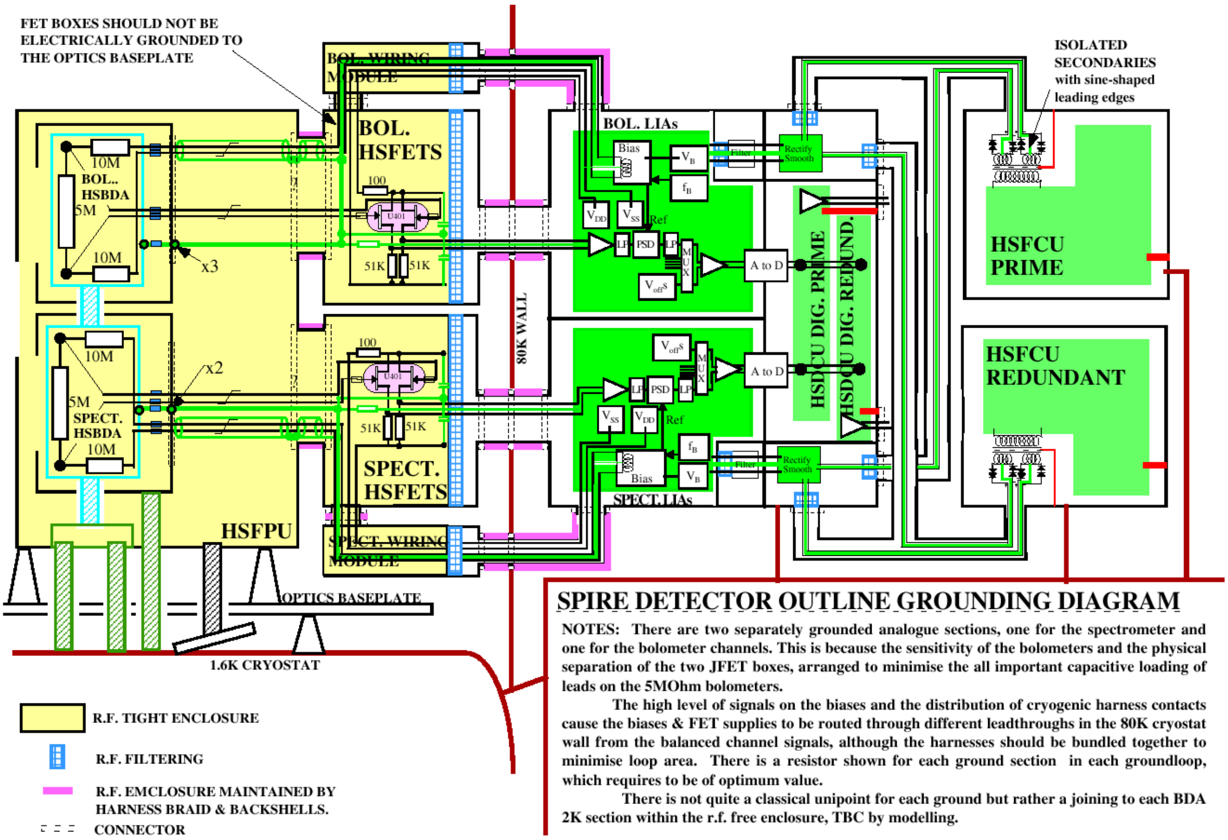

Figure 3-2 – Proposed SPIRE grounding diagram.

Four harness bundles connect the FPU to the FCU (two prime and two redundant). These harnesses carry signal and low-level current lines to power all subsystems in the FPU except for the detection system. The secondary ground points for these subsystems are formed at the secondary power supply transformers located on the PDU board. A single connection is made from the PDU to the FPU chassis.

Nine, non-redundant harness bundles carry the signal and biasing wiring for the detectors. The detection and readout system is composed of the cold focal plane electronics and the warm biasing and readout electronics. The warm electronic system comprises both low amplitude analogue electronics in the lock-in-amplifiers and high speed, 5V digital circuits for analogue to digital conversion, signal-multiplexing and digital processing with FPGAs for waveform generation and digital interfacing.

Currently, it is undetermined if the single connection between the analogue signal ground and the spacecraft will be formed at the cryogenic portion of the circuit or at the warm electronics on the SVM. If the connection is made at the cryogenic portion of the circuit, it will be via the 300-mK copper bus bars that cool the detectors, through the sorption cooler and then to the chassis of the super-fluid

Helium tank. If the system is to be grounded at the warm electronics end, then the connection from the detectors to the super-fluid Helium tank will be broken by Sapphire isolating joints in the Level 0 thermal straps. A separate digital secondary ground point will be found in the warm electronics. There has been much discussion on the tradeoffs between the two analogue grounding schemes. Much of the detail of this discussion is presented in detail in RD6.

In order to make a rational engineering decision between the various options, an Orcad model of the detection system has been constructed. This model is shown in **Figure 6-1** and **Figure 6-2**. **Figure 6-1** contains the model of the cold focal plane units and harnesses while **Figure 6-2** shows the warm read out electronics. The warm digital circuits are not included in this model but digital noise injection could be modelled through noise injection at this section of the circuit.

Once this analysis has been carried out, the results will be documented in a technical note, "SPIRE Detection System Grounding Analysis – SPIRE-RAL-PRJ-00XXX" (TBW). Requirements and/or subsystem specifications being generated as a result of this analysis will be incorporated into either the IID-B or the appropriate subsystem specification document. It is assumed that the model will give indications as to what the optimal configuration of the detection system grounding system is in order to minimise RF noise injection. Flexibility is being built into the final design so that modifications to the system can be made to improve the noise performance.

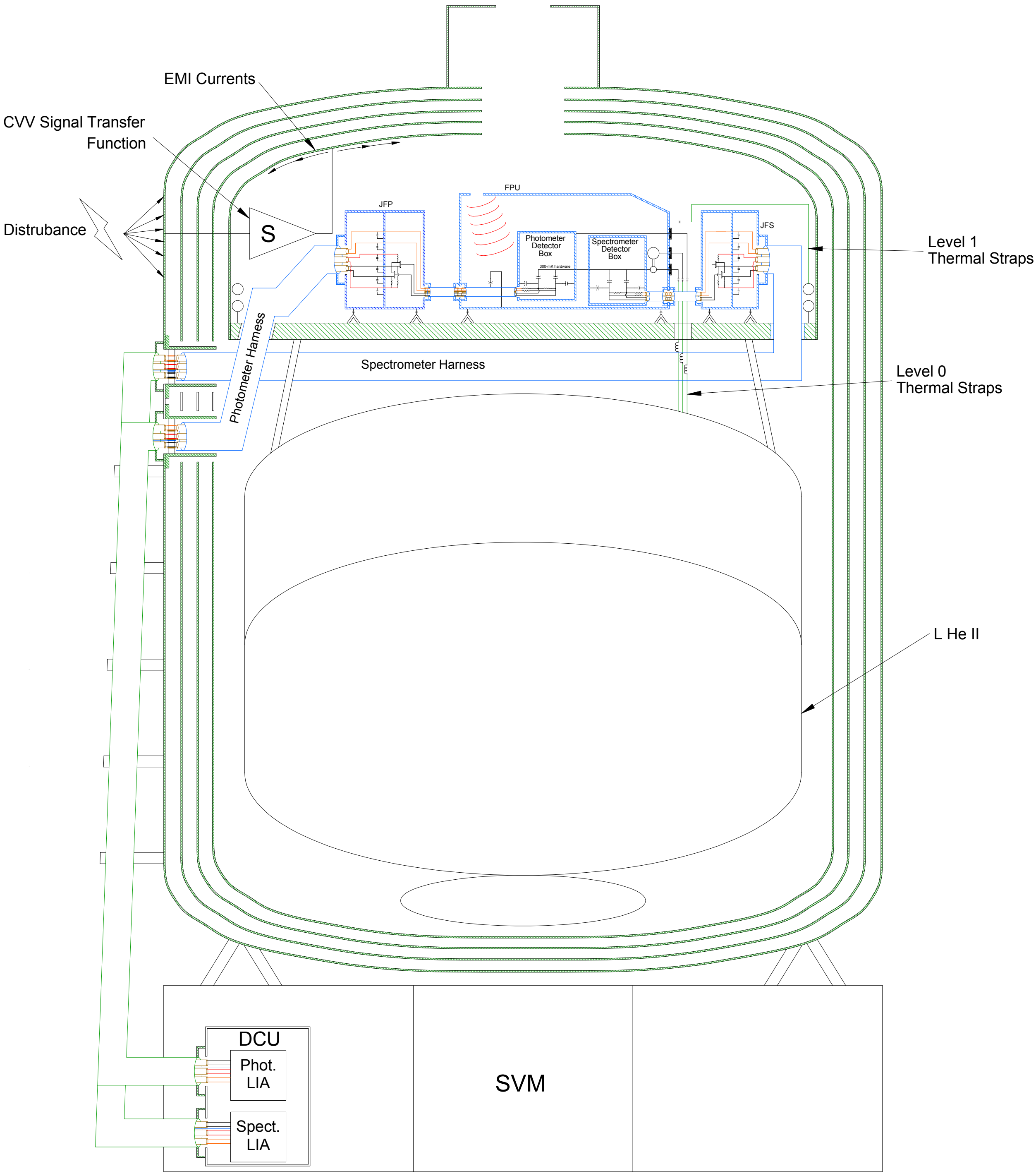

Figure 3-3 – Small scale schematic representation of cryostat attenuation EMI model . Note: This diagram omits the prime/redundant implications.

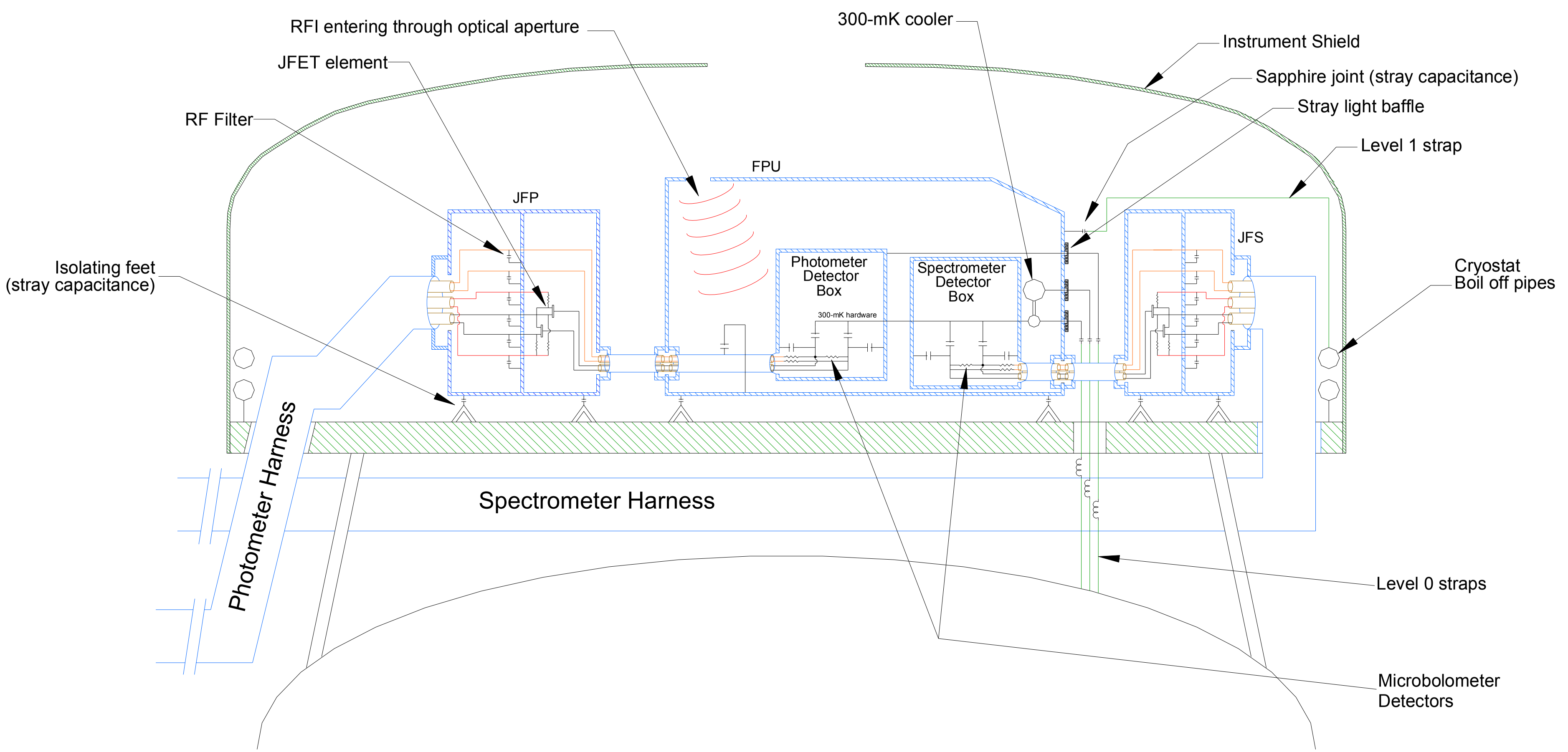

Figure 3-4 – Large scale schematic representation of cryostat attenuation EMI model.

3.2 CVV EMI characteristics

Understanding of RF coupling between the cold focal plane systems within the CVV and disturbance sources generated outside the CVV is a critical part of the understanding of the system as a whole and in the minimisation of those disturbances interfering with the detection and readout subsystem. A low frequency model of the detection system, readout electronics and cryostat has been implemented in Orcad to gain a preliminary understanding of this. This approach was adopted in the EMC analysis of the ISO LWS instrument. In this model, it is assumed that spurious electric and magnetic fields outside the cryostat generate electric currents in the structure of the cryostat. The internal and external signal bundles that run close to the metallic components of the cryostat and are electrically coupled via stray capacitances and mutual inductance and antenna coupling. The main coupling will be to the outer shields of the signal bundles. These outer shields are also coupled to the signal lines and the inner shields.

This is modelled using the Orcad schematics shown in Figure 6-1 and Figure 6-2 that are also used in the modelling of the grounding philosophy. Further development and testing of this model will be carried out during the development of SPIRE. It will be used to provide an early flag to potential problem areas in the compatibility of SPIRE, Herschel and the other instruments.

A technical memorandum documenting the methodology and the results and conclusions drawn from running the model will be contained in; “Herschel/SPIRE Cryostat Shielding Model – SPIRE-RAL-PRJ-000XXX” (TBW).

4. EMC TESTING AND QUALIFICATION PROGRAM

All qualification and acceptance EMC tests carried out on a subsystem or the instrument shall be carried out using correctly calibrated instruments. The results from these tests shall be fully documented and shall form part of the ADP for the subsystem/instrument. As a minimum, this report shall contain the following items:

1. Date of test
2. Location of Test
3. Names and contact details and qualifications of personnel
4. Configuration tested.
5. Equipment Serial numbers
6. Test conditions (Secondary testing standards)
7. Test results
8. Extra TBD details.

In this chapter, an outline of the testing will be made. At the end of this document in Appendix 2, several tables identify the tests to be carried out by a unique test procedure code. These tables enable one to cross-reference this document, the relevant EMC/EMI specification or requirement with the individual test compliance procedures.

For qualification tests, the EEE components are to be Form and Fit compliant and Performance compliant as outlined in AD 5. In practice, they shall be at least MIL-STD components with full batch traceability, sourced from the same supplier as the components used in the PFM and FS and have an extended temperature range. Component packaging shall be ceramic.

4.1 Test Conditions

Unless stated otherwise, the EMC qualification and acceptance tests will be carried out according to the procedures and conditions established in the IID-A Chapter 9 and MIL-STD-462, Test Method Standard for the Measurement of Electromagnetic Interference Characteristics. Where a conflict between these documents exists, the IID-A takes precedence.

4.1.1 Test temperature

EMC testing will be carried out at both the system level and at instrument level. Where possible, these tests will be carried out at room temperature. Unavoidably, to guarantee the validity of the results, some tests will have to be carried out with the FPU and the JFS and JFP at normal cryogenic operating temperatures. This is due to the fact that the electrical behaviour of the detectors and read out electronics is fundamentally dependant on the temperature of operation. Any specific requirements on the temperature during testing will be highlighted in the following outline of the EMC test program.

4.1.2 Primary Power

SPIRE receives 28V power from the Herschel primary power bus via 2 LCLs (there are also two separate cold redundant LCLs). During instrument level EMC testing, the power will be supplied to the instrument model by a regulated 28V power supply via a LISN. The electrical characteristics of the LISN for these tests are illustrated below.

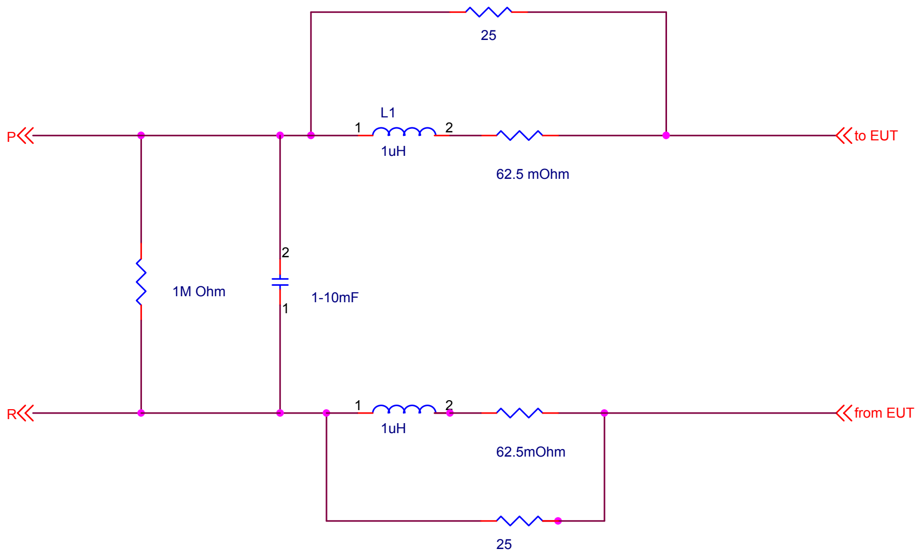

Figure 4-1 – Equivalent circuit diagram of the SPIRE LISN.

The component values are detailed in Table 4-1.

Table 4-1 - LISN Component values.

L1/L2	R1/R2	R3/R4	C1
1 µH	25 Ω	62.5 mΩ	1-10 mF

The spacecraft powers SPIRE by the main 28V power bus via two LCLs. All tests will be carried out with form and fit compliant LCLs between the LISNs and the EUT. One set of special test will be conducted with the LCLs bypassed to ensure that they do not go into current limitation mode at turn on or during any short transient power surges.

4.2 Isolation and Bonding

As has been outlined above in §3.1, it is a requirement that various parts of SPIRE be either electrically connected or isolated along with possible limits on stray capacitances. The demonstration of the means by which these requirements are met form part of the EMC Control Plan.

Where a requirement on isolation, conductance or stray capacitance exists, it is the duty of the subsystem design engineer to allow for these requirements in the design of the equipment. In designing these electrical interfaces, the engineer will take into account the long term environmental performance of the materials in the cryogenic space environment so that the requirements are satisfactorily met at the end of the mission with adequate margin.

Once the equipment has been built, each requirement will be tested to verify the achievement of the requirement. An outline of the isolation and bonding tests is shown in §6.3.1. In general the isolation and bonding tests will be carried out at subsystem level during the qualification and acceptance of the subsystem. There will also necessarily be Isolation and Bonding testing as part of the preparation procedures for the conducted and radiative EMC/EMI tests outlined below.

4.3 Conducted Emissions

The conducted emissions of EMI will be considered in two contexts. Firstly conducted emissions giving interference to other instruments and the S/C. The limits on these emissions are established in the IID-A in relation to the primary power lines and spacecraft signal interfaces and are discussed below in §4.3.1 SPIRE⇒Herschel Conducted Emissions. The second context is in relation to self compatibility (i.e. conducted emissions interfering with the correct operation of the instrument itself) is discussed in §4.3.2 SPIRE Subsystem⇒Subsystem Conducted Emissions.

4.3.1 SPIRE⇒Herschel Conducted Emissions

The electrical interfaces in SPIRE that have conducted emissions requirements placed upon them by the IID-A are the:

(i) FCU and HPCDU (power interface),
(ii) DPU and the HPCDU (power interface),
(iii) FCU mechanism launch lock confirm harness (analogue signal interface), and
(iv) DPU and the prime and redundant Mil-Std-1553b bus. (digital signal interface).

The source of conducted emissions towards the spacecraft primary power bus is through the DC/DC converter circuits. The DPU and the FCU have L-C filter circuits on its input to meet the CM and DM emissions requirements. There is a zener diode placed across the input to regulate the voltage to the driver of the converter. There is also an over-current protection circuit to limit the current drawn by the converter.

The CE testing program on the power interfaces with the spacecraft will be carried out on the EQM models of the DCU and the FCU. The CE testing of the DPU will be carried out with the AVM. These tests will require either a HCDMU simulator or a Mil-Std-1553 bus tester.

Conducted emissions from the digital to the analogue parts of the DCU are not considered here and are the responsibility of the subsystem provider. The means by which this critical design requirement is met is described in the DCU design description document.

4.3.2 SPIRE Subsystem⇒Subsystem Conducted Emissions

The internal SPIRE interfaces that are considered to potential sources of spurious conducted emissions are as follows:

1. The power supply units within the FCU,
2. The digital interfaces between the FCU and the DPU,
3. The digital interfaces between the DCU and the DPU,
4. The analogue signal interfaces between the FPU and the FCU.

There are many subsystems within the FPU, FCU and DCU that are supplied with power from a set of DC/DC converters located within the FCU. In total, there are eleven prime and eleven redundant converters. The DRCU Subsystem Specification Document contains CE limits for these converters.

The digital signal interfaces between the DPU and the other warm electronics is via RS422 differential, balanced line drivers/line receivers. These interfaces provide high levels of common mode signal rejection and should demonstrated a high level of signal quality. These interfaces will be tested implicitly (for system compatibility in terms of conducted emission/conducted susceptibility of both the DPU and the DRCU) at instrument level during the instrument level CQM program at RAL.

4.4 Conducted Susceptibility

The distinction between the susceptibility of SPIRE to conducted emissions from the spacecraft and from other instruments and the susceptibility to emissions from sources within SPIRE is made here as was made above in §4.3.

4.4.1 Herschel ⇒ SPIRE Conducted Susceptibility

The units that are susceptible to conducted emissions from the spacecraft primary power bus, the Mil-Std-1553 interface with the HCDMU and with the RTU of the CDMU are as follows:

(i) FCU and HPCDU (power interface),
(ii) DPU and the HPCDU (power interface),
(iii) FCU mechanism launch lock confirm harness (analogue signal interface), and
(iv) DPU and the prime and redundant Mil-Std-1553b bus. (digital signal interface).

The power interfaces of the spacecraft with the FCU and the DPU are designed to be immune to the level of disturbances indicated in the IID-A. They achieve this through the use of (i) zener diode regulation of the voltage, (ii) input filters.

The testing program to confirm that the required level of conducted emission immunity is detailed in §6.3.3. In summary, the S/C interfaces will be tested on the CQM model of the instrument during the instrument level CQM program. The CQM model will be delivered to ESA for testing in a refurbished ISO EM cryostat where these interfaces will be re-tested.

4.4.2 SPIRE Subsystem⇒Subsystem Conducted Susceptibility

The internal susceptibility or self compatibility of SPIRE is tested implicitly during the procedures described in §4.3.2 SPIRE Subsystem⇒Subsystem Conducted Emissions. The procedures are outlined in §6.3.3.

4.5 Radiated Emissions

4.5.1 E-Field

The IID-A states the limits of electric fields emitted from the instrument. These requirements are interpreted to apply to all components of SPIRE as both the Warm Electronic units and the cryogenic focal plane units must not exceed the RE limits. The DPU, DCU and FCU units located on the SVM will be tested at the sub-system level using the EQM models of the DPU, DCU and FCU prior to delivery to RAL. The emissions from the FPU and JFS/JFP will be measured at instrument in tests carried out at RAL prior to insertion of the instrument in the ground test cryostat at RAL.

It is important that emissions from the sub-systems within the FPU are controlled so that the detectors are not subjected to stray E-M fields. The radiated emissions from the units within the FPU are minimised by three separate design features. Firstly, all harnesses passing through the wall of the FPU are designed to carry balanced signals/currents. Theoretically, the electric field generated by each conductor of a balanced pair will cancel one another (if both the signal and return conductors are located in the same location and a current loop does not exist). The use of twisted pairs, triples etc. will ensure this. Secondly, all harnesses passing into the RF shielded cage are low pass filtered. This will eliminate high frequency common mode and differential mode voltages from propagating into the FPU. Thirdly, the signal wires are shielded by both an over braiding connected to signal ground and also an over braid around the harness bunch which is connected to the FPU chassis. These shields will greatly attenuate any eventual high frequency stray RF emissions from the FPU harnesses.

The BSM and FTS mechanisms represent possible sources of emissions within the FPU. The emissions from these items will be tested in several stages. Firstly, during tests on the CQM model of the entire instrument, the emissions from these units will be measured after attenuation by the FPU structure. This will be considered to be the qualification test of these items with respect to the IID-A §5.14.3.9. Secondly, during the warm CQM testing at RAL, system compatibility between the BSM, FTS and the detection subsystem will be tested. This will have limited validity as the detectors will be warm. The third stage of the RE testing of the BSM and FTS mechanisms will be conducted during the instrument level cryogenic CQM testing. The BSM and FTS mechanisms will be operated with the detectors observing a uniform temperature cryogenic calibration source. System compatibility will be confirmed by the absence of cross talk between the mechanisms and the detection subsystem.

4.5.2 H-Field

Much of the discussion on the magnetic RE compliance and self compatibility of the instrument is analogous to the discussion on the E-Field RE above. The IID-A RE §5.14.3.11 limits are assumed to apply to all subsystems of SPIRE. The testing and qualification of the instrument for this requirement will mirror that used for E-Field.

There are two potential sources of stray magnetic fields within the FPU that could potentially cause disturbance to the detector readout circuits; the FTS mechanism drive and the BSM mechanism drive. Both these subsystems are under active control with time varying control currents during operation of the detectors.

4.6 Radiated Susceptibility

The susceptibility thresholds outlined in IID-A §5.14.3.11 and §5.14.3.12 regarding E and H fields are assumed to apply to both the warm electronic units (DPU, DCU and FCU) along with the cryogenic units (FPU and the JFS/JFP).

4.6.1 E-Field Susceptibility

The immunity of SPIRE to spurious E-fields is maintained by enclosing the cryogenic units and the warm electronic units in RF tight enclosures. This enclosure includes all harnesses and connectors. A schematic of the means by which the RF shield is closed off is illustrated in Figure 3-3 and Figure 3-4. The RF shield around the harnesses is formed by a 360° over-braid covering the entire cable bundle. This over-braid is electrically connected at each end of the harness to RF back-shells. These backshells will mate with the equipment chassis with an EMI gasket (TBC). Inner shields around the signal conductors will form further protection against RF susceptibility (and against signal/signal cross talk).

Apertures in the chassis will be minimised as far as is possible. The joints for the various panels of the FPU will be made in such a way so that there will be no direct slots through which EMI can propagate. Each panel joint is formed by a series of shoulders that prevent EM waves from propagating directly into the FPU. The aperture in the FPU for the optical beams will have the possibility of incorporating a wire mesh that would help to attenuate the passage of RFI into the FPU.

4.6.1.1 Warm Electronics

The testing of the warm electronics will be conducted in several stages. Firstly, the QM models of the DPU, FCU and DCU will be tested for susceptibility at subsystem level concurrently with the RF emissions tests on these items. Secondly, the susceptibility will be tested warm at instrument level using the CQM model. This test will qualify the warm electronic components of the system.

4.6.1.2 Detection subsystem

For obvious reasons, it is critical that the detection systems be immune to spurious RFI. In the formulation of the EMC Test Plan, demonstration of the immunity of SPIRE to RFI poses a considerable challenge to the SPIRE project team. Some of the difficulties are listed below:

1. The bolometric detectors and read out electronics only achieve the correct sensitivity at the normal cryogenic operating temperatures. Meaningful qualification tests on the RS of the detection system must therefore be conducted with SPIRE operating at the correct temperature.
2. Qualification of the cryogenic components to the IID-A §5.14.3.10 levels in a cryogenic EMC test facility built to Mil-Std-462 or similar with anechoic lining would be completely unfeasible both in cost (no such facility exists) and in schedule (cycling the experiment in such a hypothetical facility from 4K to ambient each time to change an antennas would take weeks).
3. Based on prior experience, the RS of SPIRE will be critically determined by the temperature, routing, termination and construction of the signal harnesses. In the testing and qualification of RS of SPIRE, they need to match as closely as possible the PFM configuration in all of these respects. The only means of matching the harness routing is in a mock-up of the flight cryostat.
4. Characterisation and quantification of the electromagnetic environment inside the Herschel cryostat as seen by SPIRE is not available. The presence of apertures in the CVV will allow an

undetermined amount of RFI to penetrate the Herschel instrument shield. The influence of the cryostat structure and the other instruments is unknown. Recreating the exact flight configuration with the cryostat lid open is not possible as air would enter the cryostat and heat the cavity.

5. The electromagnetic environment inside the SPIRE ground test cryostat would be completely different to the environment seen in Herschel during flight.

It is understood that the PFM of Herschel will undergo RS testing. It is unclear however whether RS testing will be conducted and if the cryostat cover will be open or closed. If it were closed, the shielding effectiveness of the cryostat would be considerably higher than in the flight configuration thereby invalidating any RS qualification of the SPIRE detection system. If it were open, then an alternative means of providing a vacuum seal would need to be found.

Given these constraints and considerations, the following approach is proposed by SPIRE.

Firstly, the CQM model of SPIRE would be placed in the EMC test facility. After various other radiated and conducted EMC tests on various subsystems, the detection system would be tested in the configuration illustrated in Figure 4-2. The detectors themselves would be completely unrepresentative at room temperature as the impedance would be several orders of magnitude lower than at the operating temperature. Dummy detectors composed of 5MΩ exist in the BDAs that feed out through the warm electronics in the same way as the standard detectors. These dummy detectors would be used to detect any RF pick-up. The noise levels in the read out electronics train at ambient temperature will be far higher than at cryogenic temperature so this test will only indicate any gross problems with RS of the detection system.

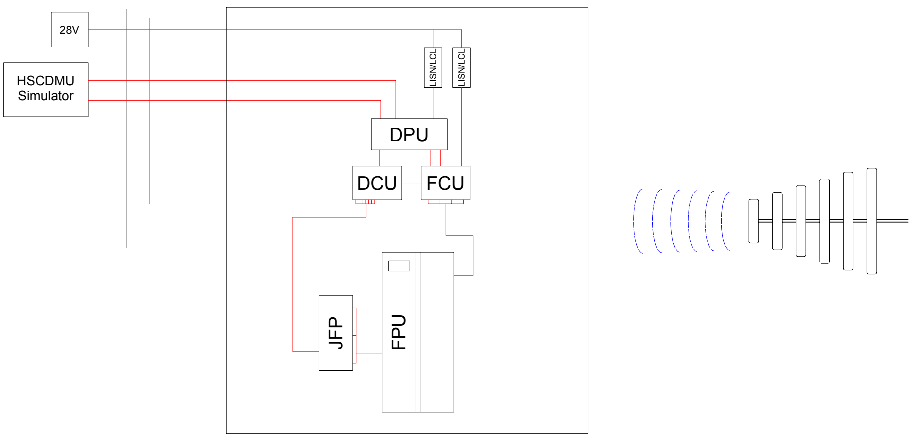

Figure 4-2 - Test set up of SPIRE for the CQM warm tests.

The second test will be through injection of CM voltages onto the detector harnesses with the CQM model of the instrument in the RAL test cryostat and at the normal operating temperature. This conducted susceptibility testing of the detection system would give further indications of the RS of SPIRE[3].

[3] For example, see Ken Javor, "*On Field to Wire Coupling vs. Conducted Injection Techniques*," p.35 EMC Test Des., Sept. 1992.

These two preliminary EMC tests will be helpful identifying any gross problems in the RS of the detection system but cannot be considered to be qualification tests for the reasons outlined above. The set-up for the third test is illustrated in
Figure 4-3. This test will be carried out at Astrium during the CQM testing of the three Herschel instruments in the adapted ISO EM cryostat. This cryostat is designed to reproduce the thermal environment of the Herschel cryostat during flight with representative thermal interfaces between the instruments and the cryostat. It has been outlined that CS and CE tests will be carried out during this program. It is proposed by SPIRE that this test be extended to RS (RE having been previously qualified).

In this test, the metal lid of the cryostat would be replaced by an RF transparent cover, adequately designed to provide the required amount of thermal isolation to prevent condensation forming on the outside cover (water condensation would reduce the transmissibility of the cryostat lid) and minimise the passive thermal loads to the inside of the cryostat. It would be desirable that the inner surface of the cover was cooled to approximately 20K and had an emissivity of close to unity so that the optical radiance at the detectors from the cryostat cover was of similar amplitude to that emitted from the primary telescope mirror in flight. (TBC)

An RF antenna would be set-up above the cryostat to irradiate the cryostat through the aperture for the optical beams passing from the primary and secondary telescope mirrors. This test would also be repeated by radiating RF through the LOU window which represent the second RF aperture to the Herschel cryostat. Adequate immunity to RFI would be demonstrated if the level of RFI pickup by the detectors was within the noise budget allocated in AD 5 (Herschel SPIRE Detector Subsystem Specification Document). It should be noted that there would probably be no opportunity to repeat the test if SPIRE failed.

Fourthly, SPIRE would undergo the EMC testing on the PFM. As stated above, it is unclear if the flight cryostat cover would be in place for these test. If it were then RS testing would have limited validity.

This four part scheme for the RS qualifying of the instrument has the following positive features:

1. The warm RS testing and the simulated cryogenic RS testing via harness voltage injection gives early indications as to deficiencies in the design.
2. Conducting RS tests in the adapted ISO EM cryostat gives the *earliest* opportunity to RS qualify the cryogenic components of SPIRE in a representative flight configuration with little extra effort over and above the existing plan.
3. This reduces both the program and budgetary risks for Herschel and all the instrument consortia.

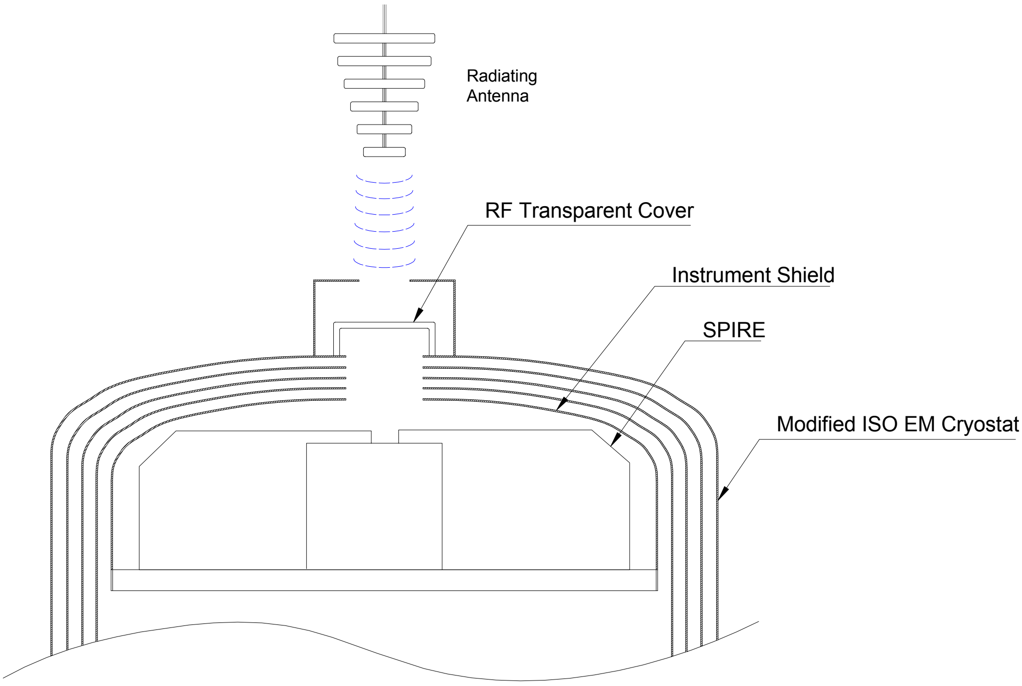

Figure 4-3 - Schematic representation of the test configuration for radiated susceptibility and Integrated System Testing of the cold focal plane units.

4.6.2 Cryogenic mechanisms

The following tests are proposed to ascertain the RFI immunity of the cryogenic mechanisms. These tests are performed warm.

EUT	Test Number	Models	Description	Test Location
BSM	BSM-RS-01	CQM	The CQM model of the BSM subsystem and its GSE are placed in the RAL EMC test facility. The Mirror is placed under active feedback control by the EGSE. E and B fields of TBD amplitude and TBD spectral distribution are radiated towards the EUT. The feedback control current of the BSM control electronics is monitored both when the unit is being radiated by the RFI and when it is turned off. A variation in the control current between these two cases would indicated that the subsystem did not meet the required RS levels.	RAL EMC Test Facility

EUT	Test Number	Models	Description	Test Location
FTS	FTS-RS-01	CQM	The CQM model of the FTS mechanism and its GSE are placed in the RAL EMC test facility. The mechanism is placed under active feedback control by the EGSE. E and B fields of TBD amplitude and TBD spectral distribution are radiated towards the EUT. The feedback control current of the FTS control electronics is monitored both when the unit is being radiated by the RFI and when it is turned off. A variation in the control current between these two cases would indicated that the subsystem did not meet the required RS levels.	RAL EMC Test Facility

4.7 B-Field RS

The discussion of the susceptibility of SPIRE to radiated magnetic fields is analogous to the discussion of E-Field radiated susceptibility. The test program to ascertain the requirements have been met is similar to the E-Field RS testing programme.

4.8 System compatibility

The following tests are planned in order to ascertain the compatibility of the cryogenic mechanism and the detection subsystem.

Culprit Unit	Victim Unit/Subsystem	Description
FTS	Detection subsystem	Detectors image the shutter in the beam obscuration position. (a uniform and constant temperature source). S-Cal temperature is adjusted with the FTS mechanism un-powered and in the in the ZPD position. The FTS mechanism is then operated under various conditions. Any signal detected by the SSW or SLW BDAs will be EMI from the FTS.
BSM	Detection subsystem	Detectors image the shutter in the beam obscuration position. (a uniform and constant temperature source). The BSM is commanded to chop and jiggle at various amplitudes and frequencies corresponding to the envelope of normal operating parameters. Any modulation of the detectors will indicate the presence of EMI

These tests are cross referenced in 6.3.6.

4.9 Electrostatic Discharge

The DPU, DCU and FCU will undergo the ESD test outlined in IID-A §5.14.3.13. The cryogenic units will not undergo these tests due to the low probability of an ESD event within the cryostat and the unwarranted risk of damage to the highly sensitive detectors within the FPU.

5. Compliance Matrix

Verification Method

1 Similarity
2 Analysis
3 Inspection
4 Review
5 Test

Verification Phase

A Design
B Development
C Qualification
D Acceptance

Table 5-1 SPIRE EMC IID-A Requirements Verification matrix.

EMC Performance Requirement Reference	Verification Methods					Document Reference and/or Remarks
	NA	A	B	C	D	
AD 1, §5.14.3.1.1		X		X	X	Differential Mode Conducted Emission on Primary Power Lines, Frequency Domain, Narrow Band
AD 1, §5.14.3.1.2		X		X	X	Common Mode Conducted Emission on Primary Power Lines, Frequency Domain, Narrow Band
AD 1, §5.14.3.1.3		X		X	X	Differential Mode Current Ripple on Primary Power Lines, Time Domain
AD 1, §5.14.3.2		X			X	Conducted Emission Common Mode Current on Signal Bundles
AD 1, §5.14.3.3		X			X	Differential Mode Conducted Susceptibility on Power Lines, Steady State
AD 1, §5.14.3.4		X			X	Common Mode Conducted Susceptibility on Power Line, Steady State
AD 1, §5.14.3.5		X			X	Conducted Susceptibility Common Mode Current on Signal Bundles
AD 1, §5.14.3.6		X			X	Subsystem common mode voltage conducted susceptibility
AD 1, §5.14.3.7		X			X	Subsystem common mode transient voltage conducted susceptibility
AD 1, §5.14.3.8		X			X	Subsystem conducted susceptibility due to switching transients on the power lines
AD 1, §5.14.3.9		X			X	Subsystem narrow band radiated E-Field emissions
AD 1, §5.14.3.10		X			X	Subsystem narrow band radiated E-Field susceptibility
AD 1, §5.14.3.11		X			X	Subsystem radiated H-Field emissions
AD 1, §5.14.3.12		X			X	Subsystem radiated H-Field susceptibility
AD 1, §5.14.3.13		X			X	Subsystem arc discharge susceptibility

6. APPENDICES

6.1 Herschel Frequency plan

During the system and satellite level testing of SPIRE, it will be useful to know the potential culprit sources of either conducted or radiated EMI and the principal frequencies at which they operate. This information is contained in Table 6-1

Table 6-1 - List of units powered while SPIRE is in one or more of its observation modes.

System	Unit	Frequency	Description
Herschel	Prime/Redundant Mil-Std-1553B	1 MHz	Long stub configuration use giving good levels of common mode rejection/tolerance.
Herschel	Transponder		SPIRE is baselined to transmit and receive TM/TC while observing.
HIFI			
SPIRE	MCU		
SPIRE	DCU		Analogue to digital converters
SPIRE	DPU		Main clock pulse
SPIRE	DCU/FPU	30-300Hz	Detector AC bias
Herschel	Solar Array	3-7 kHz + harmonics	A primary source of H-Fields
PACS			

SPIRE Unit / subsystem	Frequency Source	Frequency Range		W-form	Signal Level		Comment
		Lower	Upper		dBm	V	
S/C-DPU	1553		16 MHz	Rect.		5 V	Quartz
S/C-DPU	1553		1 MHz	Rect.		5 V	Data exchange with S/C clock
DPU	Clock		20 MHz	rect.		5 V	Quartz
DCU-SCU-MCU	DPU		312.5 kHz	rect.		5 V	Low serial link Bus clock from DPU to Subsystems
DCU-SCU-MCU	DCU-SCU-MCU		2 MHz	rect.		5 V	Fast serial link clock from Subsystems to DPU
DPU	HK data		4 kbps	rect.		5 V	Average rate
DPU	Science data		120 kbps	Pulses		5 V	Subframes average rate
DPU	DC/DC converter		131,072 kHz	Pulses		56 Vpp	

6.2 Orcad circuit models

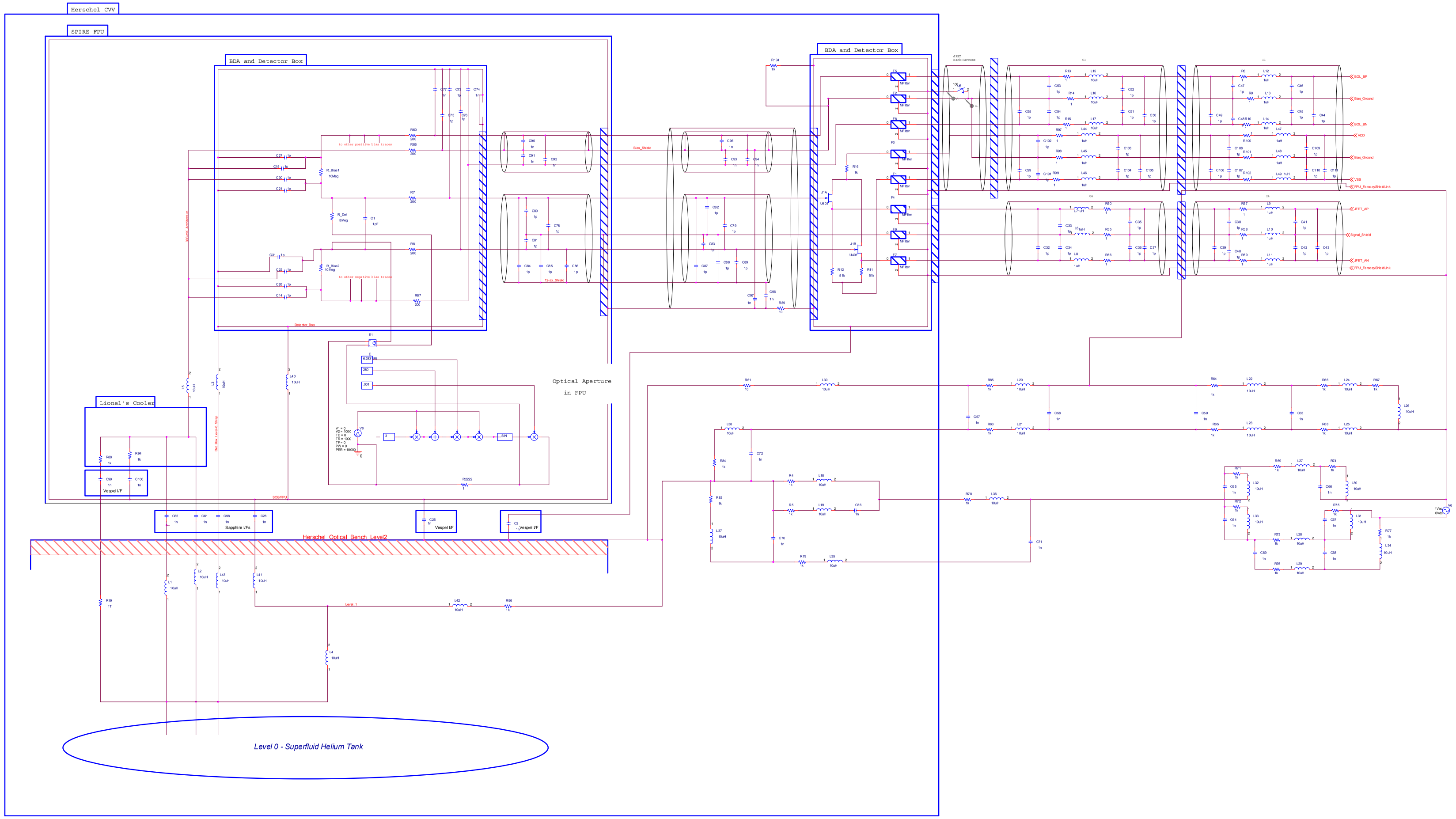

Figure 6-1 – Orcad model of the Cold focal plane electronic components showing the coupling between the structure of the CVV and the detection system.

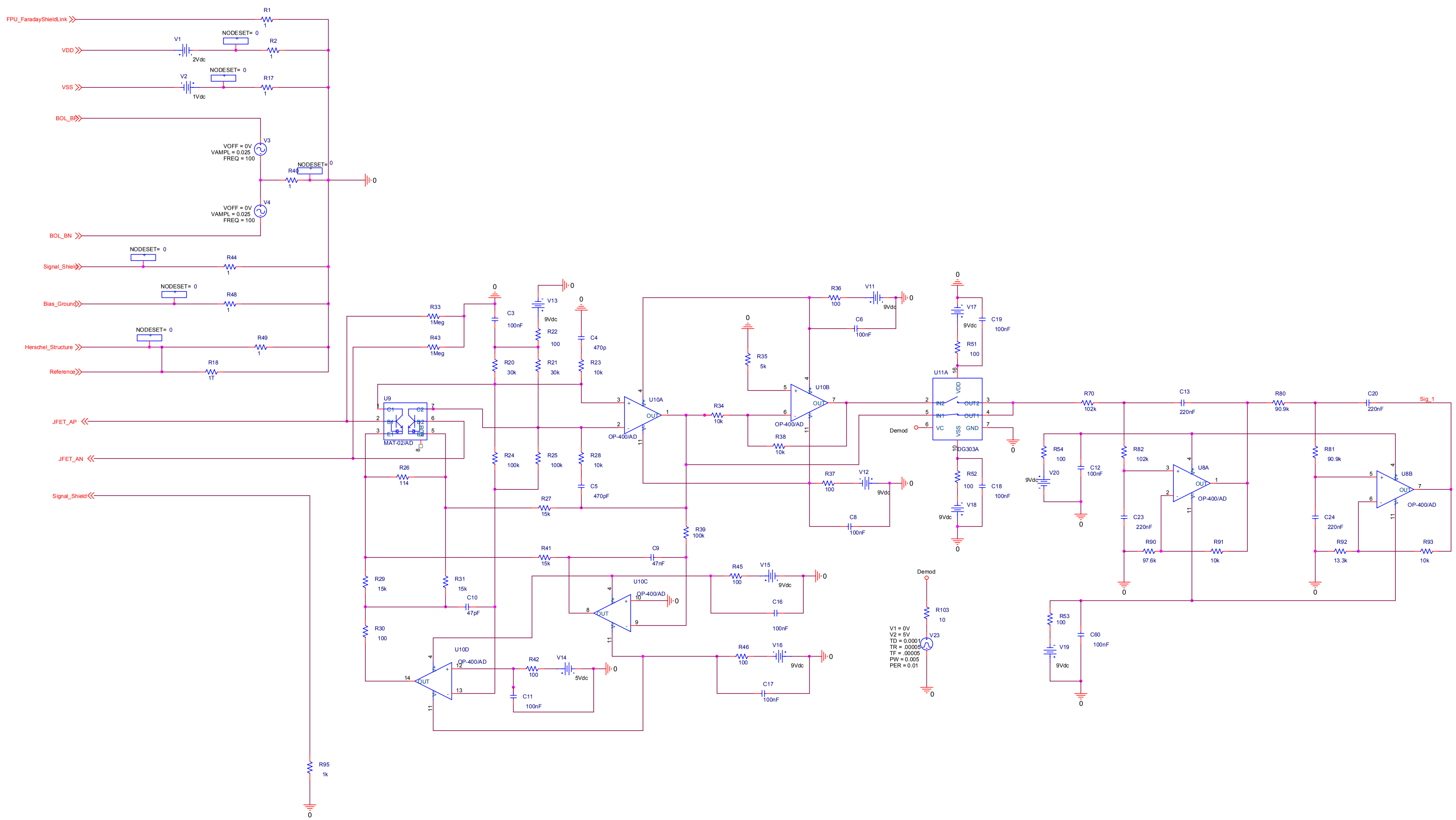

Figure 6-2 – Orcad model of the warm electronic components showing the lock in amplifier and the pre and post signal.

6.3 Test Procedures Cross-reference matrices

6.3.1 Isolation and Bonding Test Procedures

Table 6-2 – Summary of the SPIRE Isolation and Bonding requirements. These requirements are collated from the SSICDs and IID-B. The rest of this table is to be filled in with the requirements take from the subsystem ICDs and from the IID-B for the system as a whole.

EUT	Test Number	First Item	Second Item	Resistance Requirement	Capacitive Requirement	Models	Test Location	Comment
FPU								
FPU	FPU-IB-01	FPU	HOB	> 10 MΩ	< 10pF	PFM	PC	Conducted also on CQM during integration into cryostat
FPU	FPU-IB-02	FPU	Level 1 Strap	> 10 MΩ	< 10pF	PFM	PC	
FPU	FPU-IB-03	FPU	Level 0, SCO Evaporator connection	> 10 MΩ	< 10pF	PFM	PC	
FPU	FPU-IB-04	FPU	Level 0, SCO Sorption Pump connection	> 10 MΩ	< 10pF	PFM	PC	
FPU	FPU-IB-05	FPU	Level 0, Detector Box Strap	> 10 MΩ	< 10pF	PFM	PC	
FPU	FPU-IB-06	FPU Harnesses Shields F1-F27	FPU Structure	< 5mΩ	NA	PFM	PC	
FPU	FPU-IB-07	Spectrometer BDA Harness Shields	FPU Spectrometer Cover	< 10mΩ	NA	PFM	PC	
FPU	FPU-IB-08	Photometer BDA Harness Shields	FPU Photometer Cover	< 10mΩ	NA	PFM	PC	
FPU	FPU-IB-9	FPU Spectrometer Cover	SOB	< 10mΩ	NA	PFM	PC	
FPU	FPU-IB-10	FPU Photometer Cover	SOB	< 10mΩ	NA	PFM	PC	

EUT	Test Number	First Item	Second Item	Resistance Requirement	Capacitive Requirement	Models	Test Location	Comment
FPU	FPU-IB-11	FPU Wire Mesh RF Filer	FPU Photometer Cover	<10mΩ	NA	PFM	PC	
SCO								
SCO	SCO-IB-01	SCU harness signal and power wires	SCU Heart	> 10MΩ	< 5pF	PFM	PC	
SCO	SCO-IB-02	300-mK Bus Bar	Detector Boxes	> 10MΩ	< 5pF	PFM	PC	
SCO	SCO-IB-03	SCO Cooler support structure	Cooler harness backshells	<10mΩ	NA	PFM	PC	
SCO	SCO-IB-04	SCO Cooler Structure	SPIRE Optical Bench	<10mΩ	NA	PFM	PC	
BDA								
BDA	BDA-IB-01	BDA 300-mK Structure	Detector Boxes	> 10MΩ	< 5pF	PFM	PC	
BDA	BDA-IB-01	BDA Structure	Detector Boxes	< 10mΩ	N.A.	PFM	PC	
BDA	BDA-IB-02	BDA Harness Backshells	BDA structure	< 10mΩ	N.A.	PFM	PC	
BSM								
BSM	BSM-IB-01	BSM Structure	SPIRE Optical Bench	<10mΩ	NA	PFM	PC	
BSM	BSM-IB-02	BSM Harness Backshells	BSM Structure	<10mΩ	NA	PFM	PC	
JFET Boxes								
JFP	JFP-IB-01	JFET Rack	HOB	> 10MΩ	< 10pF	PFM	PC	
JFP	JFP-IB-02	Harness Backshells	JFET Rack	< 10mΩ	N.A.			
JFS	JFS-IB-01	JFET Rack	HOB	> 10MΩ	< 10pF	PFM	PC	
JFS	JFS-IB-02	Harness Backshells	JFET Rack	< 10mΩ	N.A.			
DCU								
DCU	DCU-IB-02	DCU Chassis	SVM	<10mΩ	NA	PFM	PC	

EUT	Test Number	First Item	Second Item	Resistance Requirement	Capacitive Requirement	Models	Test Location	Comment
DCU	DCU-IB-02	DCU Chassis	Connector backshells J1-J34	<10mΩ	NA	PFM	PC	
				FCU				
FCU	FCU-IB-01	FCU Chassis	SVM	<10mΩ	NA	PFM	PC	
FCU	FCU-IB-02	FCU Chassis	Connector backshells J1-J6, J9-28	<10mΩ	NA	PFM	PC	
				DPU				
DPU	SCU-IB-01	DPU Chassis	SVM	<10mΩ	NA	PFM	PC	
DPU	SCU-IB-02	DPU Chassis	DPU Harness Backshells J1-J12	<10mΩ	NA	PFM	PC	
				Harnesses				
Warm Interconnect Harnesses	WIH-IB-01	W01-W08	Idem	<10mΩ	NA	PFM	PC	Test of the end to end integrity of the harness shield
Interconnect Harnesses	IC-IB-01	I1-I13	Idem	<10mΩ	NA	PFM	PC	Test of the end to end integrity of the harness shield
Cryo-harnesses	C-IB-01	C1-C13	Idem	<10mΩ	NA	PFM	PC	Test of the end to end integrity of the harness shield
FPU non-BDA harnesses	F-IB-01	F17-F27	Idem	<10mΩ	NA	PFM	PC	Test of the end to end integrity of the harness shield
FPU BDA harnesses	F-IB-02	F1-F15	Idem	<10mΩ	NA	PFM	PC	Test of the end to end integrity of the harness shield

6.3.2 Conducted Emissions Test Procedure Cross-reference matrix

EUT	Test Number	Harness Identification	Requirement reference	Test	Models	Test Location	Test Type[4] (Q/A/D)	Remarks
FCU								
FCU	FCU-CE-01	(a) FCU J5-HPCDU Prime, (b) FCU J6-HPCDU Redundant	IID-A, 5.14.3.1.1	Power, DM, Freq.	EQM	TBD	Q	Conducted with
FCU	FCU-CE-02	(a) FCU J26 – HCDMU RTU (b) FCU J27 – HCDMU RTU	IID-A, 5.14.3.2	Signal, CM	EQM	TBD	Q	Only the interface with the S/C is tested. The analogue signal interfaces with the FPU and digital signal interfaces with the DPU are not tested here.
FCU	FCU-CE-03	(a) FCU J5 – HPCDU Prime (b) FCU J6 – HPCDU Redundant	IID-A, 5.14.3.1.3	Power, DM, Ripple	EQM	TBD	Q	
FCU	FCU-CE-04	(a) FCU J5 – HPCDU Prime, (b) FCU J6 – HPCDU Redundant	IID-A, 5.14.3.1.2	Power, CM, Freq.	EQM	TBD	Q	
FCU	FCU-CE-05	(a) I10, I11, I12, I13	TBD	CM Emissions towards RF Filters	EQM	TBD	D	
FCU	FCU-CE-06	N.A.	DRCU-REQ-95	DM Emissions	EQM	CEA	Q	Requirements on the quality of the DC/DC regulation for the subsystem secondary power supplies
DPU								

[4] Q=Qualification, A=Acceptance and D=Development

EUT	Test Number	Harness Identification	Requirement reference	Test	Models	Test Location	Test Type[4] (Q/A/D)	Remarks
DPU	DPU-CE-01	(a) DPU J1 – HPCDU Prime (b) DPU J2 – HPCDU Redundant	IID-A, 5.14.3.1.1	Power, DM, Freq.	QM1	TBD	Q	
DPU	DPU-CE-02	(a) DPU J1 – HPCDU Prime (b) DPU J2 – HPCDU Redundant	IID-A, 5.14.3.1.2	Power, CM, Freq.	QM1	TBD	Q	
DPU	DPU-CE-03	(a) DPU J1 – HPCDU Prime (b) DPU J2 – HPCDU Redundant	IID-A, 5.14.3.1.3	Power, DM, Ripple	QM1	TBD	Q	
DPU	DPU-CE-04	(a) DPU J3 – 1553 Prime (b) DPU J4 – 1553 Redundant (c) DPU J5 – 1553 Prime (d) DPU J6 – 1553 Redundant	IID-A, 5.14.3.1.2	Signal, CM	QM1	TBD	Q	
DCU								
DCU	DCU-CE-01	(a) FCU J9 – DCU J3 (b) FCU J10 – DCU J4	IID-A, 5.14.3.1.1	Power, DM, Freq.	QM1	TBD	Q	
DCU	DCU-CE-02	(a) FCU J9 – DCU J3; (b) FCU J10 – DCU J4	IID-A, 5.14.3.1.2	Power, CM, Freq.	QM1	TBD	Q	
DCU	DCU-CE-03	(a) FCU J9 – DCU J3; (b) FCU J10 – DCU J4	IID-A, 5.14.3.1.3	Power, DM, Ripple	QM1	TBD	Q	
DCU	DCU-CE-04	(a) DCU J1 – DPU J7; (b) FCU J2 – DPU J10	IID-A, 5.14.3.1.2	Signal, CM	QM1	TBD	Q	The low level analogue signal interface with the JFS, and JFP are not tested here.

6.3.3 Conducted Susceptibility Test Procedure Cross-reference matrix

EUT	Test Number	Harness Identification	Requirement reference	Test	Models	Test Location	Test Type (Q/A/D)	Remarks
FCU								
FCU	FCU-CS-01	(a) FCU J5-HPCDU Prime; (b) FCU J6-HPCDU Redundant	IID-A, 5.14.3.3	Power, DM, Steady State	QM1	RAL	Q	
FCU	FCU-CS-02	(a) FCU J5-HPCDU Prime; (b) FCU J6-HPCDU Redundant	IID-A, 5.14.3.4	Power, CM, Steady State	QM1	RAL	Q	
FCU	FCU-CS-03	(a) FCU J26 – HCDMU RTU; (b) FCU J27 – HCDMU RTU	IID-A, 5.14.3.5	Signal, CM	QM1	RAL		
FCU	FCU-CS-04	N.A.	IID-A, 5.14.3.6	CM, Sinusoid, Chassis/Ground	QM1	RAL		
FCU	FCU-CS-05	N.A.	IID-A, 5.14.3.7	CM, Transient, Chassis/Ground	QM1	RAL		
FCU	FCU-CS-06	(a) FCU J5-HPCDU Prime; (b) FCU J6-HPCDU Redundant	IID-A, 5.14.3.8	Power, DM, Transients	QM1	RAL		
DPU								
DPU	DPU-CS-01	(a) DPU J1 – HPCDU Prime, (b) DPU J2 – HPCDU Redundant	IID-A, 5.14.3.3	Power, DM, Steady State	QM1			
DPU	DPU-CS-02	(a) DPU J1 – HPCDU Prime, (b) DPU J2 – HPCDU Redundant	IID-A, 5.14.3.4	Power, CM, Steady State	QM1			
DPU	DPU-CS-03	(a) DPU J3 – 1553 Prime; (b) DPU J4 – 1553 Redundant	IID-A, 5.14.3.5	Signal, CM	QM1			

EUT	Test Number	Harness Identification	Requirement reference	Test	Models	Test Location	Test Type (Q/A/D)	Remarks
DPU	DPU-CS-04	N.A.	IID-A, 5.14.3.6	CM, Sinusoid, Chassis/Ground	QM1	RAL		
DPU	DPU-CS-05	N.A.	IID-A, 5.14.3.7	CM, Transient, Chassis/Ground	QM1			
DPU	DPU-CS-06	(a) DPU J1 – HPCDU Prime, (b) DPU J2 – HPCDU Redundant	IID-A, 5.14.3.8	Power, DM, Transients	QM1			
DCU								
DCU	DCU-CS-01	(c) FCU J9 – DCU J3 (d) FCU J10 – DCU J4	IID-A, 5.14.3.3	Power, DM, Steady State	QM1	RAL	Q	
DCU	DCU-CS-02	(c) FCU J9 – DCU J3; (d) FCU J10 – DCU J4	IID-A, 5.14.3.4	Power, CM, Steady State	QM1	RAL	Q	
DCU	DCU-CS-03	(c) FCU J9 – DCU J3; (d) FCU J10 – DCU J4	IID-A, 5.14.3.5	Signal, CM	QM1	RAL		
DCU		(e)						
DCU		(f)						
DCU		(g)						
DCU		(h)						
FPU								
FPU	FPU-CS-01	I10-I13				JPL		
JFS/JFP								
JFP	JFP-CS-01	I3-I9	Detector SSSD, JFET-TEC-03	DM		JPL		
JFS	JFS-CS-01	I1-I2	Detector SSSD, JFET-TEC-03	DM		JPL		

6.3.4 Radiated Susceptibility Test Procedure Cross-reference matrix

EUT	Test Number	Requirement reference	Test	Models	Test Location	Test Type (Q/A/D)	Remarks
FCU							
FCU	FCU-RS-01	IID-A, 5.14.3.10	E-Field	EQM		Q	Tested together with the DCU and DPU and FPU simulator.
FCU	FCU-RS-02	IID-A, 5.14.3.12	H-Field	EQM		Q	Tested together with the DCU and DPU and FPU simulator.
DPU							
DPU	DPU-RS-01	IID-A, 5.14.3.10	E-Field	AVM			Tested with dummy loads on IEEE
DPU	DPU-RS-02	IID-A, 5.14.3.12	H-Field	AVM			
DCU							
DPU	DCU-RS-01	IID-A, 5.14.3.10	E-Field				
DPU	DCU-RS-02	IID-A, 5.14.3.12	H-Field				
FPU							
FPU	FPU-RS-01	N.A.	E-Field	REM	RAL	D	Model of the SPIRE Optical Bench and Photometer Cover (no spectrometer cover). Used to determine the level of E-Field penetration into the FPU.
FPU	FPU-RS-02	IID-A, 5.14.3.10	E-Field				Confirmation that the FPU is RF tight
FPU	FPU-RS-03	IID-A, 5.14.3.12	H-Field				
JFS/JFP							
JFP	JFP-RS-01	IID-A, 5.14.3.10	E-Field				Confirmation that the JFET enclosure is RF tight
JFP	JFP-RS-02	IID-A, 5.14.3.12	H-Field				
JFS	JFS-RS-01	IID-A, 5.14.3.10	E-Field				Confirmation that the JFET enclosure is RF tight
JFS	JFS-RS-02	IID-A, 5.14.3.12	H-Field				
Harnesses							
	HAR-RS-01	IID-A, 5.14.3.10	E-Field	PFM	ESA	A	Flight configuration
	HAR-RS-02	IID-A, 5.14.3.12	H-Field				Not proposed
BSM							

BSM	BSM-RS-01		E-Field				The CQM model of the BSM subsystem and its GSE are placed in the RAL EMC test facility. The Mirror is placed under active feedback control by the EGSE. E and B fields of TBD amplitude and TBD spectral distribution are radiated towards the EUT. The BSM control current is monitored while the disturbance is turned on and off. Susceptibility is determined by the variation in the control current with and without EMI.
BSM	BSM-RS-02		H-Field				The CQM model of the BSM subsystem and its GSE are placed in the RAL EMC test facility. The Mirror is placed under active feedback control by the EGSE. E and B fields of TBD amplitude and TBD spectral distribution are radiated towards the EUT. The BSM control current is monitored while the disturbance is turned on and off. Susceptibility is determined by the variation in the control current with and without EMI.
FTS							
FTS	FTS-RS-01		E-Field				The CQM model of the BSM subsystem and its GSE are placed in the RAL EMC test facility. The Mirror is placed under active feedback control by the EGSE. E and B fields of TBD amplitude and TBD spectral distribution are radiated towards the EUT. The BSM control current is monitored while the disturbance is turned on and off. Susceptibility is determined by the variation in the control current with and without EMI.
							The CQM model of the BSM subsystem and its GSE are placed in the RAL EMC test facility. The Mirror is placed under active feedback control by the EGSE. E and B fields of TBD amplitude and TBD spectral distribution are radiated towards the EUT. The BSM control current is monitored while the disturbance is turned on and off. Susceptibility is determined by the variation in the control current with and without EMI.
System Level							
SPIRE	SYS-RS-01		E-Field	CQM	ESA	Q	SPIRE is placed within a modified ISO cryostat and cooled down to operating temperature. RF is radiated towards the focal plane through a modified RF transparent CVV cover. Interference to the various subsystems is monitored.
SPIRE	SYS-RS-02		H-Field	CQM	ESA	Q	SPIRE is placed within a modified ISO cryostat and cooled to the operating temperature. H fields are generated around the cryostat and the level of signal pickup on the various subsystems monitored.

6.3.5 Radiated Emissions Test Procedure Cross-reference matrix

EUT	Test Number	Requirement reference	Test	Models	Test Location	Test Type (Q/A/D)	Remarks
FCU							
FCU	FCU-RE-01	IID-A, 5.14.3.10	E-Field		CEA	Q	
FCU	FCU-RE-02	IID-A, 5.14.3.12	H-Field		CEA	Q	
DPU							
DPU	DPU-RE-01	IID-A, 5.14.3.10	E-Field		ISFI	Q	
DPU	DPU-RE-02	IID-A, 5.14.3.12	H-Field		ISFI	Q	
DCU							
DPU	DCU-RE-01	IID-A, 5.14.3.10	E-Field		CEA	Q	
DPU	DCU-RE-02	IID-A, 5.14.3.12	H-Field		CEA	Q	
FPU							
FPU	FPU-RE-01	IID-A, 5.14.3.10	E-Field			Q	
FPU	FPU-RE-02	IID-A, 5.14.3.12	H-Field			Q	
JFS/JFP							
							No radiated emission tests to be conducted on the JFET boxes.
Harnesses							
							No radiated emission tests to be conducted on the Harnesses.
FTS							
FTS	FTS-RE-01	FTS SSSD (TBW)	H-Field	CQM	LAM		A wire loop is placed near the BSM and the spectrum and amplitude of the emitted magnetic field measured
FTS	FTS-RE-02		E-Field				Not a baselined test at the moment. The emissions should be low enough
FTS	FTS-RE-03		Stray light	CQM			The optical encoder LED is switched on and off while the Spectrometer BDAs are functioning.

BSM							
BSM	BSM-RE-01	BSM SSSD (TBW)	H-Field				A wire loop is placed near the BSM and the spectrum and amplitude of the emitted magnetic field measured
BSM	BSM-RE-02		E-Field				Not a baselined test at the moment. The emissions should be low enough

6.3.6 System Compatibility

EUT	Test Number	Requirement reference	Models	Test Location	Test Type (Q/A/D)	Remarks
BSM	SPIRE-SC-01	N.A.	CQM	RAL	D	Crosstalk and/or interference between the BSM and the detection system is tested with the instrument at normal operating conditions in the RAL ground test cryostat.
FTS	SPIRE-SC-02	N.A.	CQM	RAL	D	Crosstalk and/or interference between the FTS and the detection system is tested with the instrument at normal operating conditions in the RAL ground test cryostat.

6.3.7 ESD Test Procedure Cross-reference matrix

EUT	Test Number	Requirement reference	Test	Models	Test Location	Test Type (Q/A/D)	Remarks
FCU	FCU-ESD-01	IID-A, 5.14.3.13	ESD	EQM	CEA	Q	
DCU	DCU-ESD-01	IID-A, 5.14.3.13	ESD	EQM	CEA	Q	
DPU	DPU-ESD-01	IID-A, 5.14.3.13	ESD	AVM	ISFI	Q	
~~FPU~~	~~FPU-ESD-01~~	~~IID-A, 5.14.3.13~~	~~ESD~~			~~Q~~	