**Issue 1.0 -** 02 June 2003
**Douglas K. Griffin**

**Aim**: To outline the Instrument level testing of the microphonic susceptibility of SPIRE

## Reference Documents:

| Number | Title | Document Number | Issue | Issue Date |
|---|---|---|---|---|
| RD-1 | Microvibrations specification | SPI-ATC-xxx | Draft 2 | 15 May 2002 |
| RD-2 | Micro vibration analysis concerning optical instruments of Herschel spacecraft | HP-ASPI-MO-218 | | 10 July 2001 |
| RD-3 | SPIRE BSM Sensitivity to microvibration | SPIRE-BSM-NOT-0005 | V 1.0 | Aug 27th 2001 |
| RD-4 | Herschel SPIRE Control System: Microvibration requirements, | | | July 17th 2001 |

## Background

Three subsystems of the SPIRE Instrument have been identified in RD-1 as being potentially susceptible to microvibrations; viz.

1. The Detection system, and in particular the BDAs,
2. The Spectrometer Mechanism, (SMEC), and
3. The Beam Steering Mechanism (the BSM)

Either the reaction wheels of the S/C and/or the other subsystems of SPIRE are assumed to be the sources of microvibrations. Alcatel has carried out an analysis of the disturbances from the spacecraft reaction wheels. (See RD-2). This study predicts that the rms amplitude at SPIRE during flight should be in the order of 5.5mg rms in the frequency band 0-60Hz. The calculated structural amplification between the source and the Herschel instruments is around 500 (depending on the assumed structural damping factors). As there is a degree of uncertainty in the calculations, margin should be added to these levels in order to ensure correct operation of SPIRE in orbit.

No specific analysis has been made on the vibration levels exported by the SPIRE mechanisms. The level exported by the SMEC should be negligible. The levels exported by the BSM will be higher as the mirror is chopped from one position to another in approximately 20ms. This will generate a quasi-impulsive reaction torque on the SOB I/F.

RD-1 makes an order of magnitude estimation of the levels at which the detectors become susceptible. RD-3 estimates the susceptibility of the BSM and RD-4 estimates the levels at which the SMEC is susceptible. These results are summarised in Table 1.

**Table 1 – Summary of the estimated susceptibility levels for various subsystems of SPIRE**

| Subsystem | Levels and comments |
|---|---|
| Detectors | 100µg rms from 5 to 100Hz. |
| SMEC | 100µg rms from 20 to 30Hz. |
| BSM | 30mg rms from 0-60Hz |

Although there is a degree of conservatism in these estimates, it is apparent that the susceptibility levels are an order of magnitude <u>lower</u> than the in-flight microvibration levels predicted by Alcatel.

Refinement of the analyses carried out by Alcatel and members of the SPIRE consortium is not being considered at the moment as these analyses have an inherent high degree of uncertainty. The approach to be adopted is to carry out microphonic susceptibility tests during the CQM and PFM programmes to quantify the magnitude of the problem for the instrument in-flight.

## S/C compatibility test outline

All testing is to be carried out in test cryostat at RAL and will be carried out in three stages.

**Stage One**: The instrument is placed inside the cryostat together with three high sensitivity accelerometers mounted orthogonally. A portable shaker is connected via a frame to the base of the cryostat close to the point where the cryogenic instrument support structure interfaces with the rigid outer stainless steel vacuum vessel wall. The doors of the cryostat are closed and the instrument is placed under vacuum.

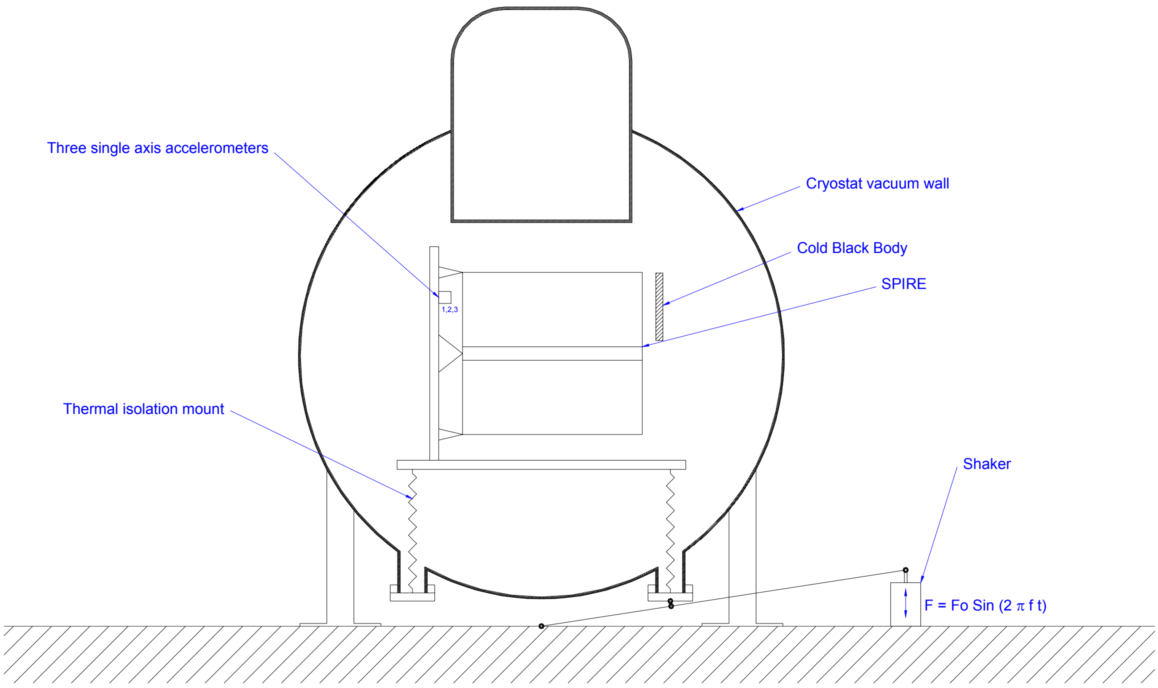


**Figure 1 - View of the instrument inside the RAL cryostat for microphonic testing.**

The amplitude of the sinusoidal drive current for the shaker is set at a given level and the frequency of oscillation is swept from 5Hz to 200Hz and the amplitude of the induced vibrations on the SPIRE mounting plate are recorded. The amplitude is set to another value and the process is repeated several times until the relationship between shaker drive current and frequency vs. acceleration level inside the cryostat has been characterised. The level will be set to achieve accelerations at the instrument interface of between approximately 0.1mg rms and 50mg rms. Once this has been completed, the vessel is filled with dry nitrogen to 1000mbar pressure and the accelerometers are removed from the tank.

**Stage Two:**

The tank is evacuated and the instrument is cooled down to operating temperature. The sorption cooler is recycled until the instrument is in its' most sensitive operating mode. The bolometer bias frequency is set to 150Hz (TBC)[1]. The aperture of the instrument is directed by a mirror towards a Cold Black Body at 4K. This lowers the optical loading of the bolometers and increases the sensitivity of the bolometer detectors. The amplitude of the shaker is set to achieve an acceleration of approximately 50mg rms according to the predetermined shaker calibration. The frequency of oscillation is swept from 5 Hz to 200Hz. Data is collected from the detectors along with the control current for the BSM and the SMEC. The test is then repeated at a lower range of induced amplitudes down to 0.1mg rms (TBC).

The susceptibility of the detection chain will be characterised by the noise increase in the acquired signals during microphonic excitation. The amplitude and frequency at which the detectors will be most sensitive is noted. Monitoring the control current and position sensor output with and without will determine the susceptibility of the two mechanisms.

**Stage Three:**

A common method used to avoid microphonic susceptibility of AC biased bolometric instruments is to adjust the bias frequency to minimise the coupling of signal into the detection chain. The effectiveness of this strategy is tested in stage three.

The frequencies and susceptibility levels of the detection chain are found by examining the results from Stage Two. The cooler is recycled and the instrument aperture is illuminated by the 4K Cold Black Body source to maximise the sensitivity of the detectors. The shaker is set to the exact frequency and twice the amplitude at which detector susceptibility was found during stage two. The bolometer bias frequency is swept from 50Hz to 300Hz and the level of microphonic noise measured.

No testing of the susceptibility of the mechanisms is carried out during stage three.

## SPIRE self-compatibility test outline

For the purpose of this test, it will be assumed that the only source of microphonic disturbance from within the instrument will be from the BSM.

The instrument is cooled within the cryostat, and the sorption cooler is recycled so that it is placed in its' most sensitive operating mode. The Cold Black Body source is placed in front of the SPIRE aperture so that the detectors see a uniform cold black source. The BSM is set to chop and jiggle at the maximum design frequency and amplitude. The signals from the SMEC position sensors and from the detectors are recorded. The BSM is then set to stare at 0,0 and the signals are recorded again. The process is repeated for a range of amplitudes.

### CQM and PFM Test Campaigns

The first test campaign will be carried out on the CQM version of the instrument. At this point, only the detector system can be tested, as the BSM and SMEC are mass dummies. It should also be noted that only one of the detectors arrays (the PLW) would be in the instrument at this time.

The second test campaign will occur during PFM AIT. As this is the flight version of the instrument, the full detector system will be tested for Spacecraft compatibility along with fully functioning BSM and SMEC. The presence of the mechanisms will also allow the self-compatibility tests to be carried out.

[1] This frequency should be the most probable frequency to be selected for use during flight. i.e. It should be the bias frequency that would be used if there were no microphonic disturbances.

**Table 2 - Inventory of main equipment required to carry out the testing.**

| |
|---|
| Portable shaker: Available |
| Audio amplifier: Available |
| Signal generator: Available |
| Three high sensitivity accelerometers: Available |
| Accelerometer signal conditioning electronics: Available |
| Frame to couple the shaker to the cryostat: To be designed |
| CQM instrument c/w a single working PLW detector chain (including JFET unit, cryoharness and bias and readout electronics) |
| PFM instrument c/w fully flight representative BSM and SMEC (as per CQM instrument plus functioning BSM and SMEC) |
| Current meter: To be sourced |

**Notes:**

1. It would clearly be advantageous to monitor the vibration levels within the cryostat with a high sensitivity cryogenic accelerometer. No suitable accelerometer was found to be commercially available, so the approach of calibrating the input (shaker current and frequency) vs. output (acceleration levels at the interface to SPIRE) was adopted.
2. It is a clear risk to the instrument development programme to not test the susceptibility of the SMEC in the instrument until the PFM AIV programme. This has proved to be unavoidable due to the constraints of the instrument and sub-system AIV programmes.
3. Ideally, the testing would be carried out on a system with a single degree of freedom, so that the response of the structure would be at the same frequency as the frequency of the disturbance input. This way, the exact frequency at which the subsystem is susceptible could be identified. The structure of the SPIRE test cryostat is not rigid and has many degrees of freedom. There will almost certainly be structural resonances in the frequency range of 5-100Hz. Thus when the cryostat is forced at a single frequency, the structure will respond with a broad spectrum of vibrations, with peaks at the cryostat natural frequencies. Therefore, the suitability of the RAL cryostat for carrying out this test is TBC.