SHIFTS Test Harness Description

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1 Scope

This document describes the test harness for the Simulator for the Herschel Imaging Fourier Transform Spectrometer (SHIFTS), which was developed initially by John Lindner and is described in his MSc thesis. The test harness is designed to verify a fresh SHIFTS installation and confirm that changes to SHIFTS leave SHIFTS fully functional.

The next section of this document provides details on how to develop a test harness for a new SHIFTS module.

One master test module (section 3.1) executes a series of tests designed to either test the cohesion of the SHIFTS software (section 3.2, shifts_test_ideal_instrument) or the individual modules which SHIFTS uses (all other test procedures). The following sections detail for each test procedure name, development history, purpose, covered SHIFTS modules, pre-conditions, data analysis, and pass criteria.

2 Adding new tests

If you add a new module to SHIFTS, please consider adding a test module as well. In this case, you will want to

- create an IDL procedure with a unique name that starts with shifts_test_ and uses only lower case letters in the folder source/test/ of the SHIFTS software structure.
- think about possibilities to verify as independently as possible the performance of the new SHIFTS module from the signal timelines which SHIFTS produces.
- add messages to the console if the test passes or if it fails.
- stop IDL execution if the test fails to allow users inspection of the data while it is still in memory.
- add a section to this document, keeping the order in which the various tests are called, in mind.

3 Test procedure descriptions

Name

3.1 shifts_test_master_control

History

Version	Date	Author	Comments
1.0	January 31, 2008	Kirk Szafranski	Original Version
1.1	February 4, 2008	Kirk Szafranski	Updated to include bolometer response test
1.2	February 29, 2008	Kirk Szafranski	Updated to include mirror temperature test

Purpose

This procedure executes all the available test cases and reports the results from the tests.

Coverage

See the coverage in the test modules below.

Pre-Conditions

None.

Analysis

The program calls each of the SHIFTS tests in the same order as they are in this document. It prints a log of the test results to the console, indicating whether a test has been executed successfully or not. When a test fails, a message is printed to the console and the test software stops allowing the user to examine the error. If a test passes then the master test control will continue with the next test and if all tests pass then a success message is displayed.

Pass Criteria

The master test control passes if all the test procedures it calls pass.

If a component fails then a meaningful error message is displayed and the user is taken to that specific module so that they may assess the situation.

Name
3.2 shifts_test_ideal_instrument

History

Version	Date	Author	Comments
1.0	February 2007	Aaron Katz	Original Version
1.1	July 5, 20077	Trevor Fulton	Fixed paths from hard-coded to user defined
1.2	January 30, 2008	Kirk Szafranski	Stopped graph output, added a pass/fail logger

Purpose
To test whether SHIFTS can reproduce the behavior of an ideal Fourier transform spectrometer, i.e. all sources of error, noise, and other real-world effects (such as filtering) are disabled.

Coverage
All modules that do not determine noise

Pre-conditions
The zeronoisesettings.sav file defines the settings: All sources of noise are turned off, the data cube is a monochromatic line of given intensity (testspectra.sav) and the profiles (beamsplitters and filers) are set to ideal settings. User controlled parameters are at their default values: two scans, scan length of 0.07cm, a primary mirror temperature of 70K and a stage speed of 0.05cm/s.

These settings are referred to as "*ideal settings*" throughout this document.

Analysis
The test checks whether SHIFTS produces cosine functions of the correct amplitude and frequency:

SHIFTS executes with the pre-conditions. The long and short wavelength interferograms are extracted as IGL and IGS respectively.

The frequency of the monochromatic source is identified from the source file. The amplitude of the expected cosine function is derived from the power in the source file and the instrument settings (throughput, etc.). An Optical Path Difference (OPD) grid and cosine functions for SLW and SSW are created with the derived amplitudes and frequency.

The measured and derived data are subtracted and divided by the expected signal for SLW and SSW to quantify the relative error as a function of OPD.

Pass Criteria
The test passes if the median relative error for SLW and SSW is less than 1%.

Name

3.3 shifts_test_sampling

History

Version	Date	Author	Comments
1.0	January 30, 2008	Kirk Szafranski	Original Version
1.1	February 16, 2008	Kirk Szafranski	Changed stage length to test from smec data instead of based on velocity * time

Purpose

To test whether SHIFTS accounts properly for the read-out frequencies of the detector arrays and the operational parameters for the SMEC (velocity, maximum stage length).

Coverage

shifts_smecmpd
shifts_make_smec
shifts_make_time

Preconditions

Ideal settings (see section 3.2).

Analysis

1. SHIFTS executes with the pre-conditions. The resulting detector timelines for one detector in both the short and long wavelength detector array are checked. The test determines the variance of the time arrays to determine if time increases at a constant rate.
2. After having determined that time increase is constant, the readout frequency is calculated as the inverse of the difference between two subsequent time values.
3. The output velocity of the stage is calculated by first only extracting the data for the first scan. This is done by reading out the stage position data by adding the coarse and the fine data (with the fine data adjusted into microns by dividing by 1000). A few points are subtracted from this value due to the acceleration phases of the stage, giving a maximum value. The velocity is determined by taking the mean of the derivative of the stage position data with respect to the smec time array from the bottom of the scan to the maximum stage position.
4. The total length of the stage travel is calculated for each scan as the difference of the largest and the smallest stage position value by again using the criteria given above for when the stage will come to a stop.

Pass/Fail Criteria

1. The variation of the time must be less than 10^{-12}.
2. The difference between the user-defined and simulated sampling frequencies must be less than 10^{-8}.
3. The simulated velocity must be within 10^{-7} of the user-defined velocity.
4. The simulated stage travel must be within 10^{-6} of the user-defined stage travel.

Name

3.4 shifts_test_scal

History

Version	Date	Author	Comments
1.0	January 30, 2008	Kirk Szafranski	Original Version
1.1	February 11, 2008	Kirk Szafranski	Added baseline calculation/subtraction to account for the 4 Kelvin difference

Purpose

To test whether the SCal module in SHIFTS produces the correct power signal.

Coverage

shifts_make_scal
shifts_thermalscal

Preconditions

This test executes SHIFTS twice:

1. The first run uses the ideal instrument settings (see section 3.2) with the following modifications: SCal is turned on and the input cube is empty (emptycube.sav). The temperature drift is turned off for both SCals and SCal2 is set to an arbitrary temperature between 1K and 100K and SCal4 is set to 0K. The SCal cavity is turned off.
2. The second run uses the same parameters as the first run, except SCal2's temperature is set to 0K and SCal4 is set to the same arbitrary temperature that was used in the first run, again with the SCal cavity turned off.

Analysis

SCal2 and SCal4 have emissivities which vary by a factor of two between the two SCal components. This test verifies this factor of two in the measured interferograms:

1. The signal of the SLW and SSW signal timelines from the first test run is determined for ZPD.
2. The signal timeline of the second test run is divided over the signal timeline of the first test run. The median of this ratio is calculated for SLW and SSW.

Pass Criteria

1. The SLW signal at ZPD divided by the mean SLW signal must be less than 10^{-12}. The SSW signal at ZPD must be the maximum signal in the SSW signal timeline.
2. The relative difference to the expected value of two must be less than10^{-7}.

Name

3.5 shifts_test_mirror_temperature

History

Version	Date	Author	Comments
1.0	February 29, 2008	Kirk Szafranski	Original Version

Purpose

To test whether SHIFTS correctly calculates the emission from the primary mirror in comparison to the power emitted by SCal.

Coverage

shifts_make_herschel
shifts_make_scal
shifts_thermalscal

Pre-conditions

The test uses the ideal settings (see section 3.2) with the following changes: the temperature of the primary mirror is set to an arbitrary temperature T and the emissivity is set to 2%. In addition, SCal is turned on and SCal2 is set to the same arbitrary temperature T and SCal4 is set to 0. The SCAL cavity is also turned off.

Analysis

SHIFTS executes with the pre-conditions. This run should produce a completely flat signal (perfect port compensation). To verify this result, the standard deviations of the signal timelines of SLW and SSW are calculated. The standard deviations are divided by the mean value of the respective signals and multiplied by 100 to get the relative deviation from a completely flat signal.

Pass Criteria

The relative deviation must be less than 1% for both signal timelines.

Name

3.6 shifts_test_photon_noise

History

Version	Date	Author	Comments
1.0	January 30, 2008	Kirk Szafranski	Original Version
1.1	February 19, 2008	Kirk Szafranski	Changed to test for an entire scan rather than just a section of one.
1.2	March 5, 2008	Kirk Szafranski	Added mirror/SCAL method of obtaining a flat line to increase the accuracy of the test

Purpose

To test whether the detector signal timeline contains the correct level of photon noise.

Coverage

shifts_powerbolo

Pre-conditions

The test procedure executes SHIFTS with ideal instrument settings (see section 3.2) with the following modifications: empty input spectrum (emptycube.sav), the stage speed is set to 0.01cm/s and the sampling frequency to 500Hz to get more data points. In addition, photon noise is turned on, SCal is switched on with SCal2 at a temperature of 50K and the telescope at a temperature of 50K and an emissivity of 2%.

Analysis

The noise in the signal timelines is determined by the standard deviations of the signal timelines. The simulated photon noise is compared to the amount of predicted photon noise (cf. formula 4.18 given in John Lindner's thesis on page 69):

$$\Delta I_{fm} = \sqrt{\left(\frac{2hc\sigma_o}{\Delta t_m}\right) I_{fm}},$$

Where ΔI_{fm} is the standard deviation of the signal, h is Planck's constant, c is the speed of light, Δt_m is the master time interval (0.002s), I_{fm} is the average power incident on the bolometers at a master time interval and σ_0 was set to 22.2 and 40 cm^{-1} for the SLW and SSW arrays respectively.

Pass Criteria

The relative error between the simulated and expected photon noise must be less than 5%.

Name

3.7 shifts_test_electronic_noise

History

Version	Date	Author	Comments
1.0	February 4, 2008	Kirk Szafranski	Original Version
1.1	March 5, 2008	Kirk Szafranski	Added mirror/SCAL method of obtaining a flat line to increase the accuracy of the test

Purpose

To test whether the detector signal timeline contains the correct level of electronic noise.

Coverage

shifts_detectorsig

Pre-conditions

The test executes SHIFTS with ideal instrument settings (see section 3.2) with the following changes: The electronic noise is turned on and the Noise Level is set to $10nV/Hz^{1/2}$; the signal sampling frequency is set to 500Hz; the speed is set to 0.02cm/s to generate more data; an empty sky (emptycube.sav) is used as astronomical input; the emissivity of the primary mirror is set to 2% at a temperature of 50K and SCal2 is set to a temperature of 50K. SCal4 and the SCal cavity are turned off.

Analysis

The electronic noise in the signal timelines is determined by the standard deviations of the signal timelines. These values are compared to the predicted amount of electronic noise, which is given by: $\Delta I_{fm} = NoiseLevel * (\Delta t_m)^{1/2}$. ΔI_{fm} is the standard deviation of the signal, Δt_m is the master time interval of 0.002s.

Pass Criteria

The relative error between the simulated and the predicted electronic noise must be less than 5%.

Name

3.8 shifts_test_cosmic_rays

History

Version	Date	Author	Comments
1.0	January 28, 2008	Kirk Szafranski	Original Version
1.1	February 4, 2008	Kirk Szafranski	Added a test for negative signal shifts due to cosmic particle impacts
1.2	March 3, 2008	Kirk Szafranski	Changed to convert signal into volts so that the negative shifts would not represent negative power.

Purpose

To verify that the cosmic ray noise module executes properly.

Coverage

shifts_powerbolo

Pre-conditions

This test executes SHIFTS twice:

1. For the first execution, SHIFTS uses the ideal instrument settings (see section 3.2) with the following modifications: the cosmic ray noise is turned on, the impact frequency set to 10000 per minute; the electronics are turned on in order to convert the signal from W to V.
2. For the second execution, SHIFTS uses the ideal instrument settings (see section 3.2) with the following modifications: the electronics are turned on so that the signal will be converted from W to V.

Analysis

1. It is expected that SHIFTS will produce negative signals due to the cosmic ray hits. The minimum values of the SLW and SSW signal timelines are determined to verify this result.
2. An analysis of the timelines from both test runs verifies whether the second execution of SHIFTS created more consistent data than the first execution. For each test run and for each detector array, the timelines are separated into the two scans and subtracted from one another. The averages of the absolute differences are computed.

Pass Criteria

1. The minimum values of the SLW and SSW signal timelines must be negative.
2. The average of absolute differences for the first execution of SHIFTS must be larger by a factor of at least 10 than for the second execution of SHIFTS.

Note that these tests cannot confirm whether the number and amplitude of glitches was simulated as selected by the user. The test procedure performs only a very crude check on the functionality of the cosmic ray noise module.

Name

3.9 shifts_test_velocity_jitter

History

Version	Date	Author	Comments
1.0	January 31, 2008	Kirk Szafranski	Original Version
1.1	February 7y, 2008	Kirk Szafranski	Updated to include a test for jitter amplitude in addition to the jitter location test

Purpose

To test whether the velocity jitter of the stage is simulated correctly.

Coverage

shifts_make_smec, shifts_smecMPD

Pre-conditions

This test procedure executes SHIFTS twice:

1. For the first execution, this test uses ideal instrument settings (see section 3.2) with the following modifications: the velocity jitter is turned on with an artificial profile (artificial_velocity_jitter.sav) that was designed to be of the same number of elements as the array that SHIFTS uses to process the velocity jitter. This jitter profile contains on-zero elements only at a single frequency just below 95Hz with an error amplitude of 100,000 cm/s/Hz.
2. The second run is identical to the first run with the only exception of the artificial jitter profile (artificial_velocity_jitter1.sav). The second execution features a jitter profile with the amplitude deprecated by a factor of 10 but at the same unique frequency.

Analysis

1. The power spectrum of the stage velocity is calculated. The jitter frequency is determined as the maximum value of the calculated jitter spectrum. The amplitude and the frequency of the unique non-zero entry in the artificial jitter profile are determined.
2. The velocity jitter for the two test runs is determined from calculating the standard deviations of the velocity timelines for the first and second execution of SHIFTS are calculated.

Pass Criteria

1. The relative error between the simulated jitter frequency and the jitter frequency in the artificial jitter spectrum must be less than 5%.
2. The ratio of the velocity jitter in the first test run over the velocity jitter in the second test run must be within 10% error of the value 10.

Name
3.10 shifts_test_bolometer_response

History

Version	Date	Author	Comments
1.0	February 4, 2008	Kirk Szafranski	Original Version
1.1	February 19, 2008	Kirk Szafranski	Changed to test for logarithmic slopes instead of entire signals, added special version of mcp and detectorsig to eliminate multiplicative error factors.

Purpose
To test whether the user-selected time constant of the bolometer response is implemented.

Coverage
shifts_detectorsig

Pre-conditions
This test procedure executes SHIFTS twice:

1. For the first execution, this test uses ideal instrument settings (see section 3.2) with the following modifications: The bolometer response is turned on and the time constant values set to 10ms; the detector read-out frequency is set to 800Hz to generate more data.
2. For the second execution, this test uses ideal instrument settings (see section 3.2) with the detector read-out sampling frequency set to 800Hz.

Analysis
The timelines from the second run are subtracted from the timelines of the first run. Data are taken from the portion of the interferogram between the two scans where the stage stands still. The timelines of the differences in signal are computed. The natural logarithm is applied to the absolute of the difference signal timelines. The inverse of the detector response time constant is determined as the linear fit to the slope of the 30 data points after the stage has reached standstill inbetween the two scans.

Pass Criteria
The relative error of the simulated detector response time constant must be less than 5% for SLW and SSW.