SUBJECT:	**SPIRE Spectrometer Detector Thermal Time Constant Derivation Procedure**		
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Change Record

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Draft 0.1	14 April 2009	First version
Draft 0.2	20 April 2009	References to Figures 4.5-4.8 changed to 3.1-3.4 Added a reference to the SPIRE Spectrometer channel time constant calibration file description document Modifications based on comments from PDI Updated Figure 2.1.

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Glossary

BDA	Bolometer Detector Array
DCU	Detector Control Unit
FT	Fourier Transform
LHS	Left Hand Side
LPF	Low-pass filter
MPD	Mechanical Path Difference
MR	Medium Resolution
OPD	Optical Path Difference
RHS	Right Hand Side
SLW	Spectrometer Long Wavelength array
SMEC	Spectrometer MEChanism
SNR	Signal to noise ratio
SPIRE	Spectral and Photometric Imaging REceiver
SSW	Spectrometer Short Wavelength array
TBD	To Be Determined
TBW	To Be Written
ZPD	Zero Path Difference

1. Introduction

The purpose of this document is to describe the method used to derive the thermal time constants for the SPIRE Spectrometer detectors. Some background on this correction will be provided in §2. The method itself will be described in §3. The major issues involved in automating this process will be presented in §4.

1.1 Documents

1.1.1 Applicable Documents

Number	Document Name	Document Number	Issue
AD01	Glitch Simulation from the SPIRE Detector Electronics	SPIRE-UOL-DOC-002496	1.0
AD02	SPIRE Spectrometer Pipeline Description	SPIRE-BSS-DOC-002966	1.2
AD03	Spectrometer Time Domain Phase Correction	SPIRE-BSS-DOC-XXXXXX	Draft 0.1
AD04	Delivery of Calibration Data From External Sites to RAL	http://www.herschel.be/twiki/bin/view/Spire/SpireIntDoc030700	

1.1.2 Reference Documents

RD01	SPIRE Spectrometer Thermal Time Constant calibration file description document	SPIRE-BSS-DOC-XXXXXX	Draft 0.1

2. BACKGROUND

One of the underlying assumptions the derivation of the thermal time constants is the validity of the model used to describe the SPIRE readout electronics and the thermal behaviour of the SPIRE spectrometer bolometers. A detailed discussion of this model is presented in [AD01].

In practice, this model is difficult to apply because the precise thermal time constants for the SPIRE spectrometer detectors are not known to sufficient accuracy *a priori*. It is therefore necessary to derive a procedure that can be employed to determine the thermal time constant for each of the SPIRE spectrometer detectors. In addition, it should be possible to implement this method in an automated fashion as a manual implementation can potentially be a time-consuming task and is subject to errors during execution.

2.1 Directional dependence

The automated method that is used to determine the thermal time constant of the SPIRE spectrometer bolometers involves a binary search. A key assumption made by this method is that the interferograms recorded by the SPIRE Spectrometer should exhibit little to no directional dependence. Here the term directional dependence refers to how the recorded interferograms differ depending on the direction of the SMEC for that particular scan. An example of directional dependence is shown in Figure 2.1.

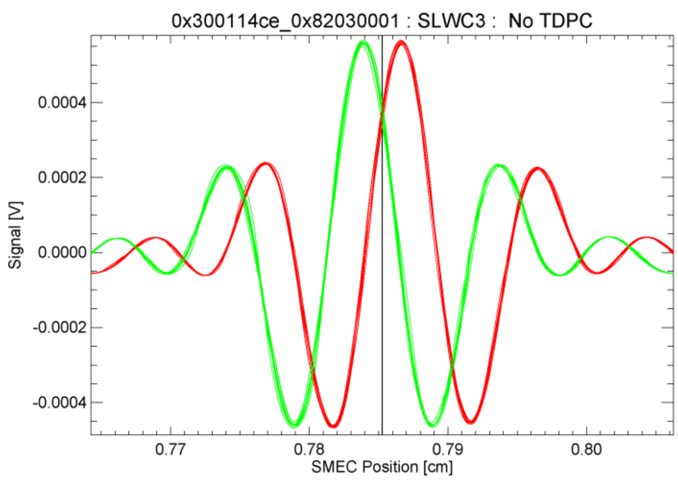

Figure 2.1: Interferograms recorded for channel SLWC3. No attempt has been made to compensate for the delay induced by the readout electronics and the bolometer thermal response. Note the separation between the forward scans (green) and the reverse scans (red).

3. PROCEDURE

The procedure to derive the thermal time constant for each SPIRE Spectrometer bolometer is listed below. These steps are applied for each detector in the Spectrometer Detector Timeline.

1. **Choose a thermal time constant.** This is an initial guess of the thermal time constant (τ_0=20ms). This step essentially populates the SPIRE Spectrometer thermal time constant calibration product [**RD01**] for the given detector.
2. **Derive the time convolution kernel.** Compute the frequency response from the combination of that from the readout electronics and a simple RC low pass filter with the thermal time constant.
3. **Apply the time convolution correction.** Shift the SPIRE spectrometer detector voltages by applying the time convolution method [AD03].
4. **Interpolate the detector signals onto an evenly-spaced SMEC position grid.** Perform the interpolation of the shifted detector timelines onto the evenly-spaced SMEC position timelines. This procedure is described in [AD02].

5. **Determine ZPD.** Determine the position of ZPD for all scans for a given channel within a given observation. The location at which the magnitude of the difference between the recorded signal and the mean interferogram signal is the greatest is defined as the position of ZPD (see §4 for a description of exceptional cases). Separate these ZPDs into two groups; one group that contains the ZPDs of the forward scans, the other group containing the ZPDs of the reverse scans.
6. **Compare Median Forward/Reverse ZPDs.** Compare the median forward ZPD to the median reverse ZPD for all of the scans of the observation.
    a. If the difference between the median ZPDs is less than some predetermined ε (ε=0.000XXXcm):
        i. The given thermal time constant is valid. Exit the iterative loop.
    b. else:
        i. If the median forward ZPD is less than the median reverse ZPD increase the thermal time constant otherwise decrease the thermal time constant.
7. **Iterate.** Repeat steps 3—6 above until the median ZPDs converge or a predetermined number of iterations (10) have been attempted.

The plots in Figure 3.1—Figure 3.4 show the aforementioned procedure in action. After the initial guess (τ=20ms) is made, the positions of ZPD for the resultant interferograms are compared. The process is repeated until the difference between the positions of ZPD for the forward scans agrees with those for the reverse scans. The end result is that not only is the thermal time constant derived for the given detector, but so too is its position of ZPD.

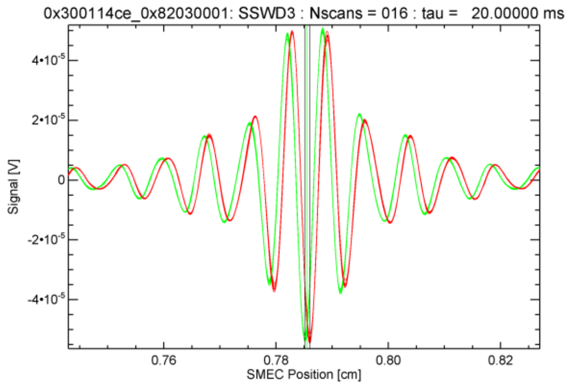

Figure 3.1: Interferograms generated after the initial guess of the thermal time constant. The median forward ZPD and median reverse ZPD are shown as vertical black lines.

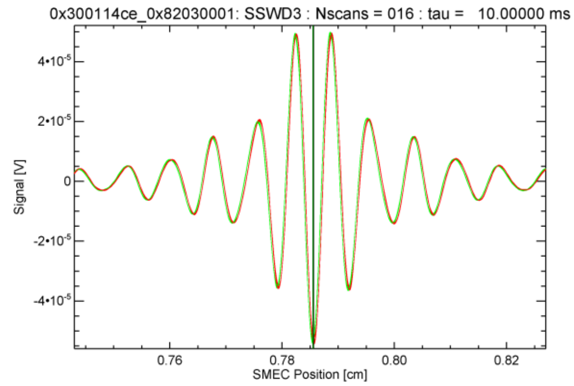

Figure 3.2: Interferograms generated after the first iteration of the binary search.

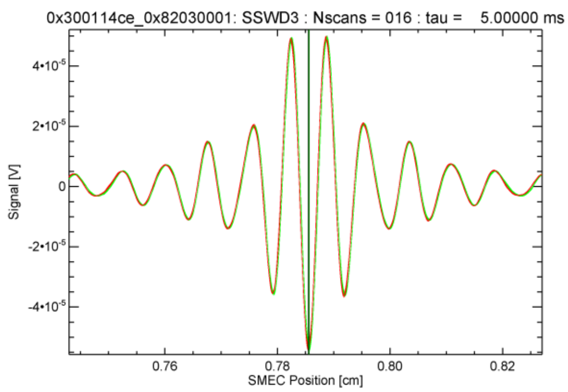

Figure 3.3: Interferograms generated after the second iteration of the binary search.

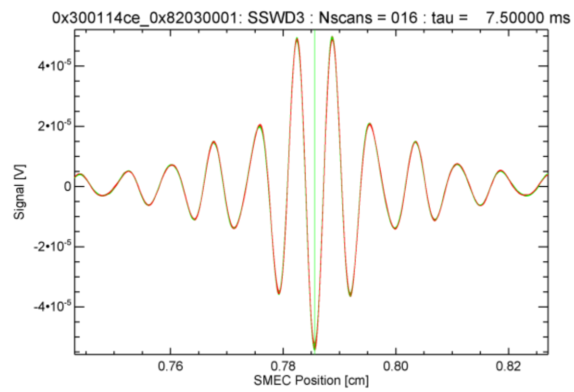

Figure 3.4: Interferograms generated after the third iteration of the binary search.

4. Issues Related to the Derivation of the Spectrometer Time Constants

This section presents some of the challenges related to the automatic derivation of the SPIRE spectrometer detector time constants. Along with each of these issues, a potential solution is provided.

4.1 Clipped Signals

Clipped signals -- detector signals whose raw values exceed the bounds of the ADCs -- have the potential to create major problems for the binary search method. Consider two examples of clipped signals, those clipped away from the position of ZPD (Figure 4.1) and those clipped at the position of ZPD (Figure 4.2).

1. **Clipped signals away from the position of ZPD.** If the recorded interferograms contains clipped signals but those signals are not at the position of ZPD (Figure 4.1), the binary search method can be used as normal. This is a minor issue since not only can the thermal time constant for the given detector still be determined, but so too can the position of ZPD.
2. **Clipped signals at the position of ZPD.** Clipped signals pose a major problem is if they occur in the region at the position of ZPD (Figure 4.2). This situation is problematic as it makes it impossible to determine the precise position of ZPD for a given iteration of the binary search. It is however possible to use the binary search method even in this case because of the underlying principle that there is no directional dependence on the resultant interferograms. As such,

secondary or tertiary interferogram lobes may also be used as if they were the primary ZPD lobe. While the use of secondary or tertiary lobes does allow for the correct determination of the thermal time constant it also precludes the coincidental determination of the position of ZPD.

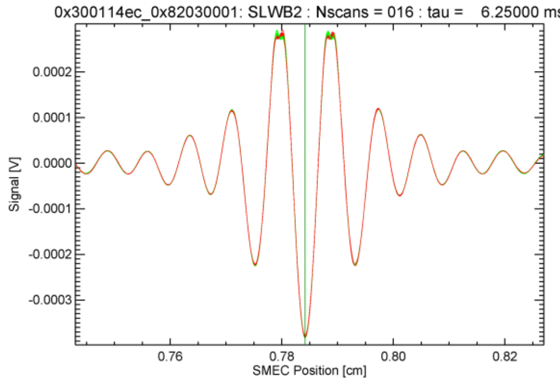

Figure 4.1: Interferograms clipped off the position of ZPD.

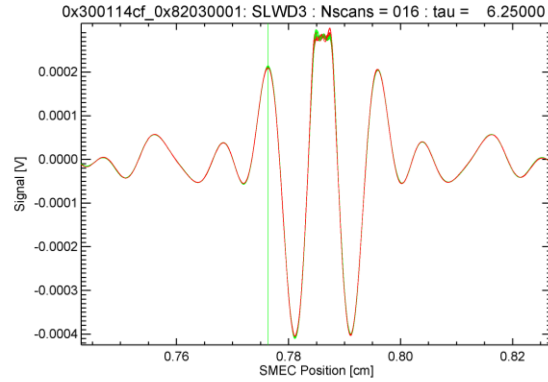

Figure 4.2: Interferograms clipped at the position of ZPD.

4.2 Well Compensated Interferograms

Well compensated signals (Figure 4.3, Figure 4.4) pose a potential problem to the automated procedure. The reasons are similar to those that are caused by signals clipped at the position of ZPD; the interferograms that result do not contain a clear ZPD signal, which makes convergence of the binary search method unlikely. As is the case for signals clipped at ZPD (§4.1), however, it is still possible to use the binary search method even the signals are well-compensated; secondary or tertiary interferogram lobes may also be used when performing the binary search. Just as was the case for signals clipped at the position of ZPD, however, the use of secondary or tertiary lobes precludes the coincidental determination of the position of ZPD.

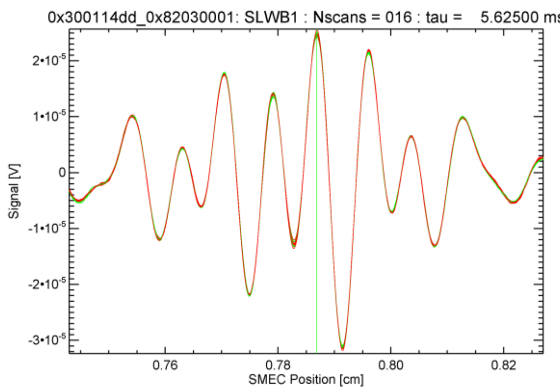

Figure 4.3: Well-compensated interferograms; SLW Array.

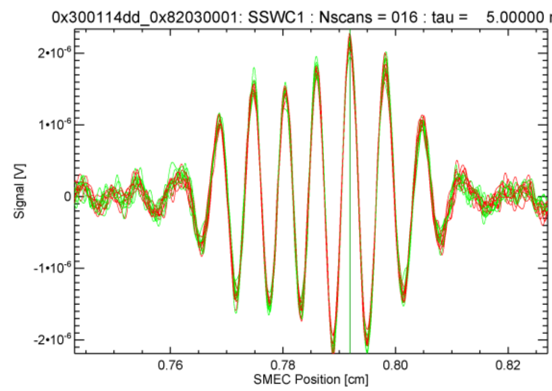

Figure 4.4: Well-compensated interferograms; SSW Array.

4.3 Orientation of the Signal at ZPD

The most minor of the issues related to the automated determination of the pixel time constants and the position of ZPD is the orientation of the detector signal at the position of ZPD. In the case of detector signals that are neither clipped nor well compensated, the orientation of the detector signal at ZPD depends on two factors; the detector array (SLW or SSW) and which of the two input ports (telescope or SCAL) is dominant. Table 4.1 summarizes the orientation of the detector signal at the position of ZPD for the various possibilities, while Figure 4.5—Figure 4.8 show examples of the primary orientation of the interferograms at the position of ZPD for the various scenarios.

BDA	Dominant Port	Orientation at ZPD
SLW	Telescope	Positive
SLW	SCAL	Negative
SSW	Telescope	Negative
SSW	SCAL	Positive

Table 4.1: Orientation of the measured interferograms at ZPD.

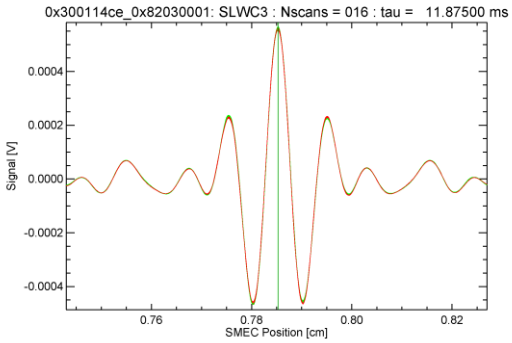

Figure 4.5: Interferogram orientation when the Telescope port is dominant; SLW Array.

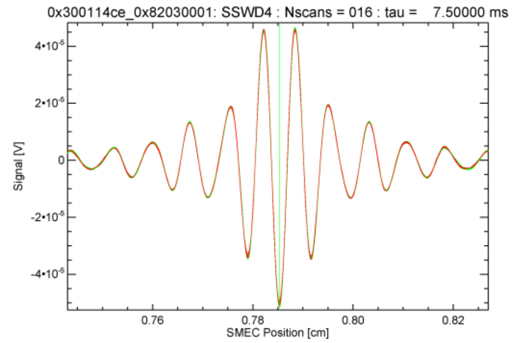

Figure 4.6: Interferogram orientation when the Telescope port is dominant; SSW Array.

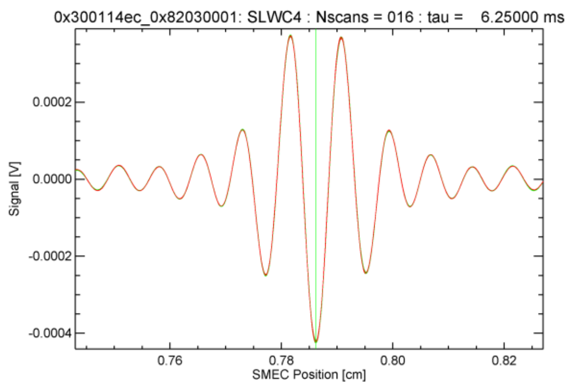

Figure 4.7: Interferogram orientation when the SCAL port is dominant; SLW Array.

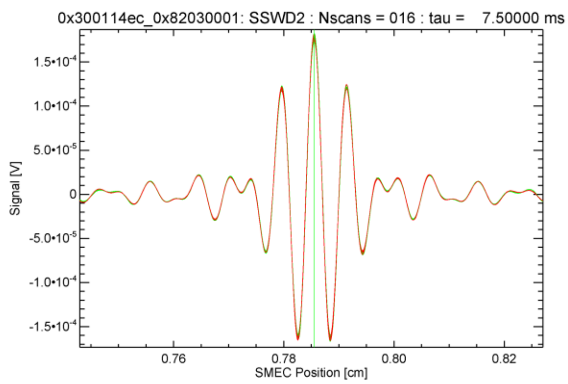

Figure 4.8: Interferogram orientation when the SCAL port is dominant; SSW Array

It should be noted that this issue is considered minor since, while the orientation at ZPD cannot be known absolutely *a priori*, quick inspection of the detector timelines is all that is required to make this determination.