0 Scope

This technical note is the disposition for HR-SP-ATC-ECR-3, which raises the issue of the specification of the measurement accuracy of the BSM against what is written in IRD.

1 Introduction

The BSM specification document (SPIRE-ATC-PRJ-000460 v3.3 Section 4.1.8) specifies the accuracy of the measurement of the absolute position of the mirror as 0.0005^{o} at the mirror or 0.025 arcsec on the sky. The Instrument Requirements Document (SPIRE-RAL-PRJ-000034 issue 1.1) gives the requirement as 0.01 arcsec on the sky. There is also some ambiguity in the IRD requirement on the required stability of the mirror. The same requirement that gives the required accuracy also states:

> *"The knowledge of the mirror position shall be equivalent to a stability of 0.2 arcsec (on sky, 0.004° on BSM) rms in the 0.03 to 25Hz frequency band."*

This is not clear as to why, or how to interpret the requirement given the requirement on the position accuracy is already stated as 0.01 arcsec. Also it is neither clear in the requirement on the stability nor on the measurement accuracy whether this applies radially or per axis.

In this note I report on a model of the response of the photometer to instabilities in the mirror position and on the ability to correct for the instabilities given the measurement uncertainty and sampling frequency.

2 Modelling the response

A mathematical model of the system has been constructed in IDL as described in figure 1. Both the "real" signal – i.e. a model response of what actually happens to the signal as the mirror moves the image of a point source across the instrument response function – and the reconstructed signal – how we might attempt to correct for the problem given the position information from the BSM – are computed in the model. The reconstructed signal can be divided into the real signal in an attempt to remove the influence of the instability.

Two issues can then be addressed by this model:

- Whether the absolute instability of the BSM is a problem in terms of loss of response or systematic noise.
- Whether the accuracy and frequency of the position sampling are sufficient to correct for any problems.

The BSM instability is, in the first instance, crudely modelled as a single time constant "RC" type response to impulse from the servo mechanism running at 200 Hz. The position filtering can also be left out so that the BSM response is unfiltered jitter at 200 Hz. The amplitude of the jitter at 200 Hz in the filtered case was increased such that the rms jitter of the filter positions was 0.2 arcsec. In the unfiltered case the rms of the 200 Hz jitter was set directly to 0.2 arcsec. Note that x and y position arrays were created independently so the radial jitter amplitude was, in effect, larger than 0.2 arcsec. This allows for a more straightforward interpretation of the specification on the BSM.

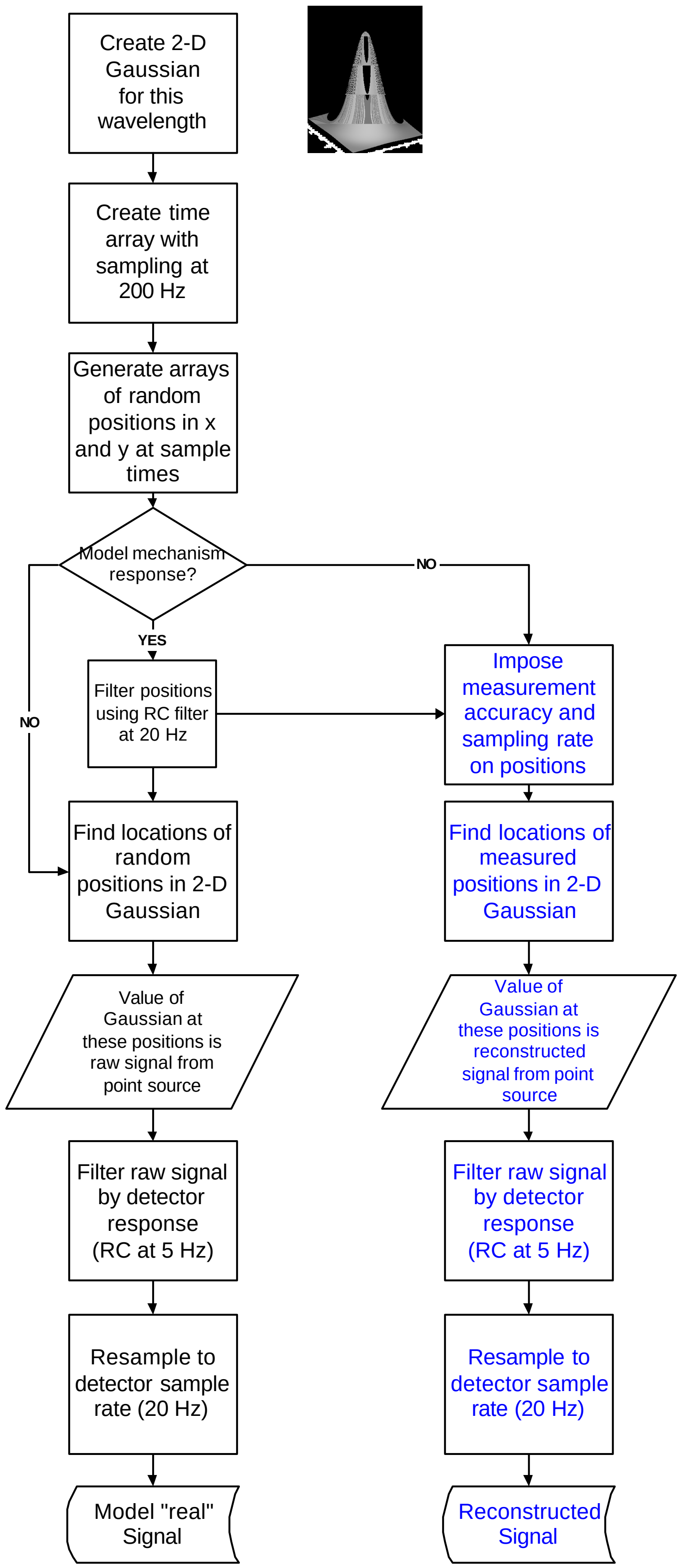

Figure 1: Flow diagram of mathematical model of effect of Beam Steering Mirror instability on photometer signal.

3 Results

Two basic situations were modelled both at 250 µm with 0.2 arcsec rms jitter post 20 Hz position filter; 0.025 arcsec position accuracy; 5 Hz detector response and 20 Hz sampling of the detector response. The first simulation was for 100 Hz sampling of the position and the second for 40 Hz sampling. Figure 2 shows the calculated signal as a function of time for the 100 Hz sampling and figure 3 shows the same for 40 Hz sampling.

For the 100 Hz case the equivalent signal to noise in 1 second for the simulated signal was 16000. When the reconstructed signal was used to correct the simulated "true" signal the S/N was 27000. With 40 Hz position sampling the results were 18000 and 15800 respectively. As a check on the effect of the position filtering I ran the simulation without the 20 Hz position filter and obtained S/N of ~27000 without correction and ~25000 with correction for 100 Hz position sampling. Repeated runs with the same input parameters showed the uncertainty on the S/N result is about ±2000.

4 Conclusions

I think it is safe to assume that the S/N achievable in 1 second under any reasonable assumptions will never approach anything above 10000 as statistical noise will dominate. Therefore allowing the BSM position stability requirement to be 0.2 arcsec rms per axis and having a measurement accuracy of 0.025 arcsec will not have any significant impact on the instrument performance in photometer mode. This remains true even if we undersample the position in time leading to aliasing in the reconstructed signal. Whether we are obliged to undersample will depend on the real response of the BSM in each axis, which is not yet known. Any (very small) DC loss in signal can always be corrected for using the reconstructed signal from the measured position.

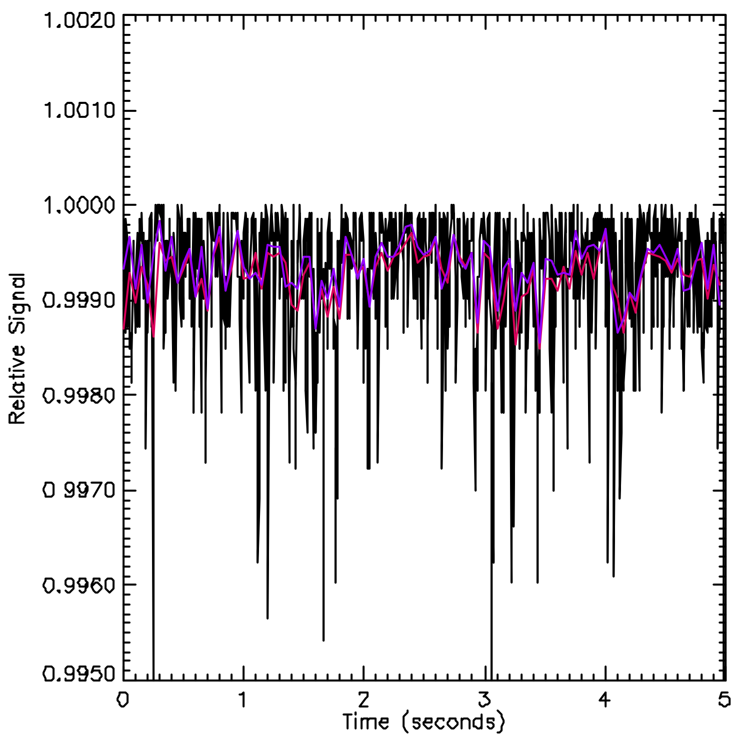

Figure 2: Simulated signal versus time for the case described in the text with 100 Hz sampling of the position used to reconstruct the signal. The simulated signal before filtering by the detector response is the black trace; after filtering is the red trace and the "reconstructed" signal is the purple trace

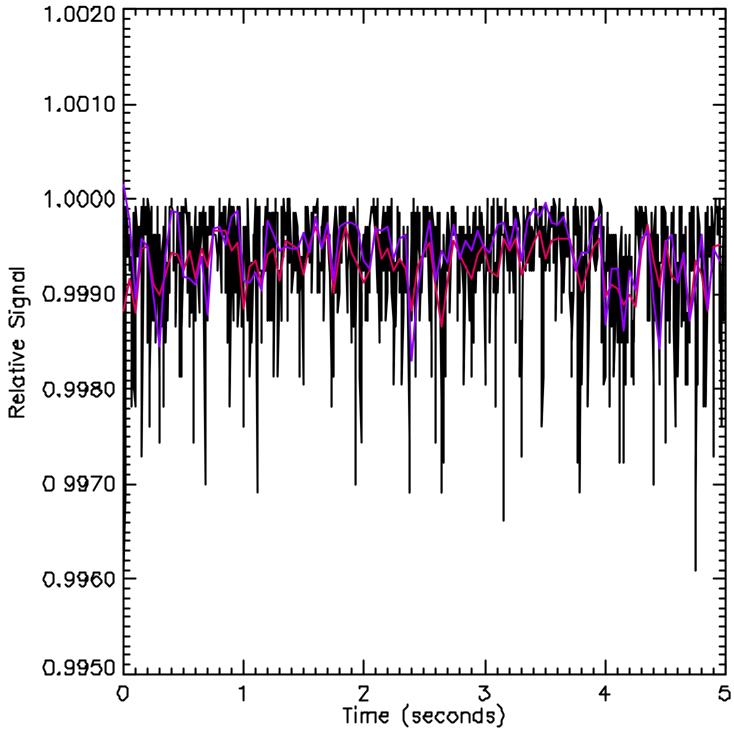

Figure 3: As figure 2 but with 40 Hz position sampling used to reconstruct the signal.

In the spectrometer the achievable S/N is always going to be limited by the velocity errors in the scanning mechanism and instability in the BSM at the 0.2 arcsec rms level will have no impact on the spectrometer performance.

The requirements shall be re-written as (new text in blue):

IRD-BSMP-R06	Stability	The angle on the sky must not vary by more than 0.2 arcsec per axis over 60 sec at the commanded mirror position. The mirror position shall also have a stability equivalent to 0.2 arcsec rms per axis in the 0.03 to 25 Hz frequency band	SPIRE-RAL-NOT-001457
IRD-BSMP-R07	Position Measurement	The absolute knowledge of the mirror position shall be equal to or less than the equivalent of 0.025 arcsec on the sky in each axis.	*Ditto*