Jitter Loop Transfer Function

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1 Introduction

This technical note describes the tests performed on the Jitter stabilization loop of the ARGOS 's WFSs. The main aim of the Jitter loop is to reduce the average Tip and Tilt on the three pupils, in order to work with the Shack Hartman wavefront sensor around the Tip/Tilt null position.

A sensor, a Real Time Computer and an actuator compose the Jitter stabilization loop. There are 6 channels, one for each star and direction, and each channel is controlled by a single stabilization loop.

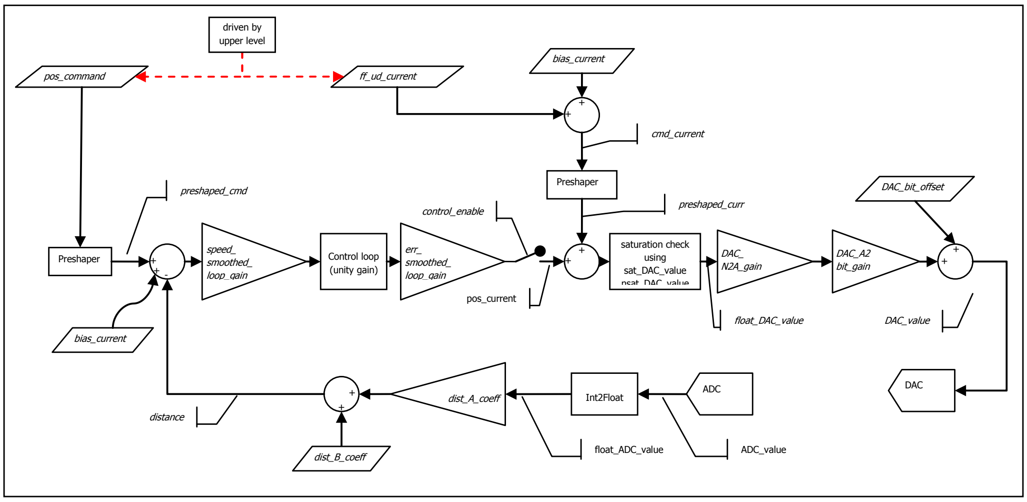


Figure 1: Hvc Loop.

The sensor of the Jitter Loop is the Laser Guide Star Wavefront sensor, the measure of the jitter signals are the averages of the slopes on the three stars in the x and y directions (average Tip/Tilt on the pupils). The jitter signals are expressed in "slopes" units, in the range [-1,+1], that corresponds to a range of [-2.4″, +2.4″] of angles on sky. The RTC calculate the jitter commands at ∼1 kHz and use them to control the Tip/Tilt mirrors, mounted on the actuators.

The actuators are `PI-S334`[1] Piezo heads: a Piezo head is controlled by an high frequency loop at ∼ 70 kHz (Figure 1), driven by the jitter signals. The routine of the Hvc loop implements a digital IIR filter with 3 taps both on the position error and on the absolute position. This is typically used to implement a derivative control acting as electronic damper. The filter is completely independent for each mirror actuator. The output is converted to voltage and sent to the HV driver and then to the corresponding Tip/Tilt mirror actuator. The feedback actuator position is acquired by the strain gauge available on the Tip/Tilt mirror. In parallel with the position close loop a command proportional open loop contribution is included in the algorithm, this contribution is important to obtain the maximum performances at the step response where the close loop is relatively slow while this output proportional contribution allows at the actuator to reach the final position as fast as possible (Feed Forward)[2].

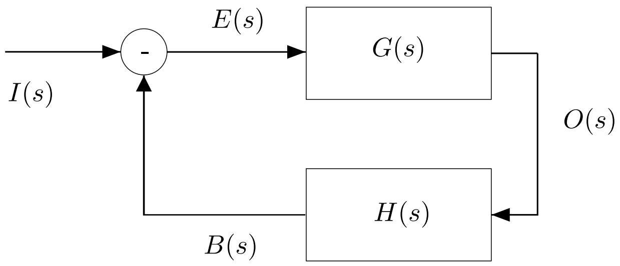


FIGURE 2: Jitter loop.

The performances of the Jitter stabilization loop are described by the The Jitter Closed Loop Transfer Function is defined as:

$$JCTF(s) = \frac{O(s)}{I(s)} = \frac{G(s)}{1 + G(s)H(s)} \tag{1}$$

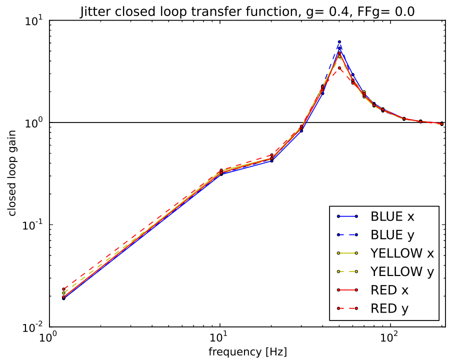
and the Jitter Open Loop Transfer Function is defined as:

$$JOTF(s) = \frac{B(s)}{E(s)} = G(s)H(s) \tag{2}$$

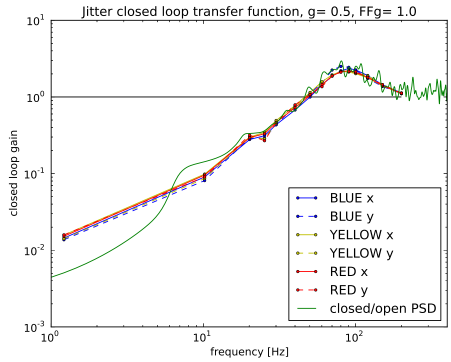
where $I(s)$ is the input signal, $G(s)$ is the plant transfer function (the WFS and the RTC), $O(s)$ is the output signal (the average of the slopes measured on a WFS), $H(s)$ is the feedback transfer function (the RTC) and the node of the feedback path is the Piezo Mirror. All the variables are expressed in the Laplace domain.

2 Measures

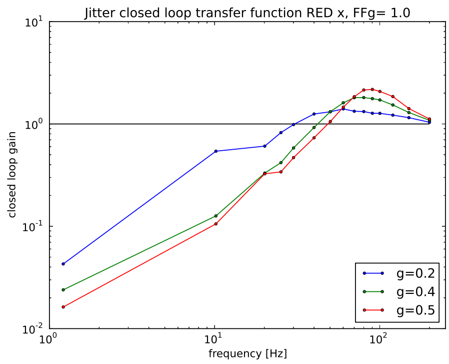
The measures were taken at the telescope (during the commissioning run #5[3]), illuminating the secondary mirror with the Calibration Unit and pushing on the Adaptive Secondary Mirror sinusoidal disturbances of the mode 1 (Tilt) of 200 nm amplitude. We injected the disturbances with several frequencies, from 1 Hz to 200 Hz and we took a series of snapshots of the system, in particular a set of ~4000 samples of the jitter signals (in ~4 s) for each snapshot. The slopes used to compute the jitter signals are evaluated with the Threshold Center Of Gravity algorithm ($T = 48\,\mathtt{ADU}$). For each frequency we close the loop setting different Feed Forward gains of the high frequency Hvc Loop, from FFg=0.0 to FFg=1.0, and setting different gains of the Jitter Loop, from g=0.0 (open loop) to g=0.6. The gain g of the Jitter Loop represent the amount of signal used to control the feedback.



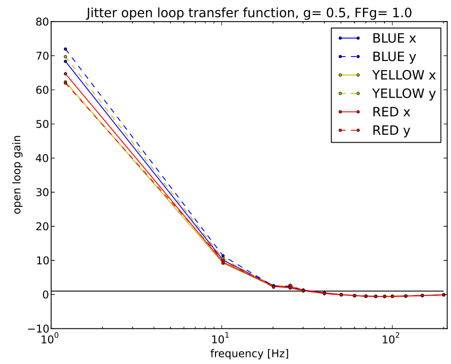
(a) Jitter Closed Loop Transfer Function, g=0.4, FFg=0.0.



(b) Jitter Closed Loop Transfer Function and ratio between closed loop PSD and open loop PSD, g=0.5, FFg=1.0.



(c) Jitter Closed Loop Transfer Function of one channel with different gains.



(d) Jitter Open Loop Transfer Function, g=0.5.

FIGURE 3: Jitter Loop Transfer Functions.

3 Analysis

The first step of the analysis consist in the calculation of the Power Spectral Density of the jitter signals for the six channels independently for all the snapshots. Focusing on one gain and one FF gain we evaluate the PSD of the jitter signals at the frequency of the injected disturbance, in open ($O_o(f)$) and closed ($O_c(f)$) loop. Equations 3 and 4 provides the two transfer functions for the Jitter stabilization loop as function of the jitter signals.

$$JCTF(f) = \frac{1}{1 + G(f)H(f)} = \frac{O(f)}{G(f)I(f)} = \frac{O_c(f)}{O_o(f)} \quad (3)$$

$$JOTF(f) = G(f)H(f) = \frac{B(f)}{E(f)} = \frac{O_o(f) - O_c(f)}{O_c(f)} \quad (4)$$

where $O_c(f)$ is the jitter signal in closed loop and $O_o(f)$ is the jitter signal in open loop. The $JCTF$ is normalized for the plant transfer function $G(f)$.

In Figure 3(a) are reported the closed loop transfer function for each channel with the gain set to 0.4 and the FF gain to 0.0. Figure 3(b) shows the closed loop transfer function (g=0.5, FFg=1.0) and, over plotted, the ratio between the entire PSD of the Jitter in closed loop (O_c) and the entire PSD of the Jitter in open loop (O_o) when the Adaptive Secondary Mirror was injecting in the system an atmospheric disturbance (equivalent to a seeing of 1.2″). Figure 3(c) shows the trend of the $JCLTF$ in function of the gain g, with the FF gain set to 1.0. In Figures 3(d) are reported the open loop transfer functions for each channel with gain g=0.5 and FFg=1.0.

4 Conclusions

As explained in the Introduction (Section 1), the contribution of the Feed Forward is important to reach the performances desired. The trend of the Jitter Loop Transfer Functions reflect this behavior, with high FFg the transfer function has an higher cut frequency (f_c) and a lower overshoot peak ($JCLTF(f_o)$, f_o is the overshoot frequency). As summarized in the Table 1 the cut frequency increase from 31 Hz to 48 Hz with respect on the Feed Forward gain increase (from 0.0 to 1.0) and in parallel the overshoot peak decrease of a factor 2. So in conclusion the Jitter loop is working as expected and the Feed Forward is important to reach these performaces.

Table 1: Jitter Closed Loop Transfer Function parameters for each gain setup, the values are evaluated as the average of the six channels.

Loops gains	f_c [Hz]	f_o [Hz]	$JCLTF(f_o)$
FFg= 0.0, g= 0.4	31	50	4.8 ± 0.8
FFg= 0.5, g= 0.6	43	70	3.9 ± 0.4
FFg= 1.0, g= 0.5	48	80	2.2 ± 0.1

References

[1] *ARGOS, PiezoPIS334*. URL: http://aowiki.arcetri.astro.it/ARGOSPublic/PiezoPIS334.

[2] Mario Andrighettoni. *ARGOS BCU mini-crate SYSTEM DESIGN*. 2014. URL: http://aowiki.arcetri.astro.it/pub/ARGOSPublic/BCU/LBT-MIC-TRE-00910-0001_Rev3.pdf.

[3] *ARGOS, commissioning run #5*. URL: http://aowiki.arcetri.astro.it/ARGOSPublic/DiaryRun5.