MRO Delay Line

ICS/Delay Line Information Flow

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rev 0.3

15 June 2006

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Table of Contents

Objective

To list the information that must be transferred between the Interferometer Control System (ICS) and the delay lines in order to perform automated observations.

Scope

This document lists the information that we anticipate must flow between the ICS and the delay line system in the controls implementation used for the operations phase of MROI. The document is intended to inform the design of this implementation, in particular the design of the interface between the ICS and the delay lines.

The following are beyond the scope of this document:

- The communication protocols used to transfer the information
- Discussion of whether or how the prototype delay line control software could be re-used
- Discussion of whether the ICS communicates directly with sub-systems of the delay lines
- Discussion of commissioning requirements (e.g. for testing the delay lines). This document only considers operational requirements

This document has been written with no knowledge of the delay-line-specific features in the RTC framework.

1 Introduction

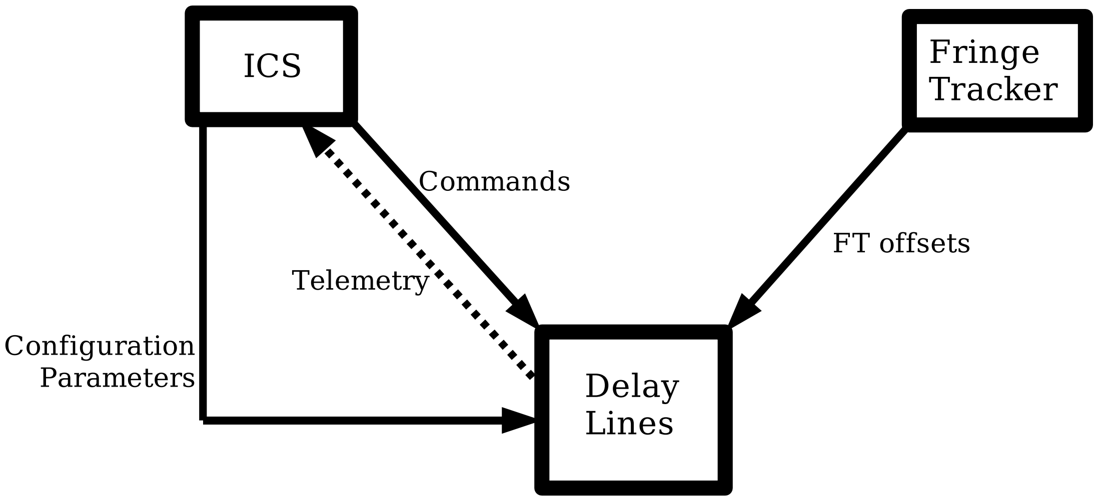
We assume the generic control system architecture shown in Drawing 1. For the purpose of this document, the Delay Line Control System (DLCS) is treated as a “black box”, although we describe how some functions will be implemented in the prototype DLCS where this might be helpful.

This document lists commands, originating from the ICS, that the DLCS must support to allow automated operations. Tables giving subsets of the commands are interleaved with explanation of what the commands are for.

The commands listed will require responses to indicate validity and success or failure, but the form of such responses is not discussed here. “Telemetry” streams are only mentioned where these are required for normal operations (as opposed to debugging, for example). Note that we use a very loose definition of telemetry here; some quantities listed as “status” in the prototype DLCS protocols document are described as “telemetry” below.

We also list certain “configuration parameters” needed by the DLCS that we anticipate will be managed by the ICS (because they are accessed by multiple interferometer subsystems).

When the DLCS detects an error condition, it will inform the ICS of this fact (the communication protocol used to signal errors is outside the scope of this document). This version of the document does not list the error conditions.



Drawing 1: Generic MROI control system architecture, showing the interfaces to the delay lines outlined in this document. Arrows indicate the primary directions of information flow.

The delay lines incorporate the following control loops. The roles and implementation of these are outlined in the “Trolley Concept Description” supplied previously.

- Steering (roll control)
- Shear
- Optical Path Delay (OPD)

All three loops must be active while recording interferometric data. In normal operations there should be no need to deactivate any of the loops during the night. However, it would be prudent for the DLCS to understand commands to activate and deactivate each loop:

Command	***Parameters***	***Note***
Activate steering	—	
Deactivate steering	Open-loop steering position	
Activate shear loop	—	
Deactivate shear loop	Open-loop tip-tilt position	
Activate OPD loop	—	
Deactivate OPD loop	—	

In addition to the three loops listed above, the cat's-eye focus will need to be adjusted occasionally (at most a few times per night), based on temperature readings and the empirically-determined relationship between the focus error and temperature at various points on the cat's-eye structure. Adjustments will be made by closing a loop (until the adjustment is complete) around the focus position sensor, while driving the focus actuator piezo motor.

Command	***Parameters***	***Note***
Query focus position	—	
Set focus position	New position	
Apply focus offset	Offset from current position	

When OPD control is active, each delay line attempts to follow a defined axial trajectory (i.e. trolley position and velocity as a function of time). In the prototype DLCS the VME CPU is responsible for automatically switching between tracking and slewing OPD modes (refer to the “Trolley Concept Description”), depending upon the magnitude of the OPD error signal.

A special OPD control mode is used to drive the trolley to the datum and then reset the metrology count, see Section 4.1. This is required for both the prototype and production delay lines.

Only three types of OPD trajectory are required for operations:

- **Sidereal Trajectory**: Compensate geometric delay to follow fringes from an astronomical target
- **Stop**: Servo trolley to constant position
- **Constant Velocity**: Used for:-
    - Measuring the mean axis of the delay line pipe in order to define the fiducial direction used by the MROI alignment system
    - Determining the fiducial position for the shear sensor — see Section 4.2

The DLCS must provide a capability to add OPD offsets measured by the Fringe Tracker to the sidereal trajectory.

1.1 Coordination of Multiple Delay Lines

In principle, each delay line is capable of following an OPD trajectory that is completely independent of the trajectories of the other MROI delay lines.

In practice, the delay lines required for an observation would all follow sidereal trajectories for the same astronomical target (of course the trajectories are different since they relate to different baselines). A subset of the delay lines might not be required for a particular observation — these could follow a “stop” trajectory.

There is one degree of freedom associated with the set of delay line trajectories, since only the relative optical delays between beams matter. A sensible way of choosing this “common offset” (equivalent to the “fixed offset” in the COAST delay lines, but this is a misnomer since it need not be constant) would be to continuously calculate the value that minimises the longest metrology path.

This document does not suggest any commands to change how the common offset is calculated (they are not needed if the same criterion is always used). If such commands were supported, the DLCS might need to access configuration parameters not listed in this document in order to calculate the common offset appropriately (however, minimising the longest metrology path would not require any extra configuration parameters).

2 Trajectory Definition

A sidereal trajectory for a delay line is completely defined by the following pieces of information:

- Local Apparent Sidereal Time
- Diurnal aberration
- Apparent right ascension (RA) and declination of the observing target (i.e. its geocentric apparent place)
- Baseline parameters:
    - Vector baseline between the corresponding UT and an arbitrary "reference UT" (use same reference for all delay lines)
    - Pathlength variation as a function of pointing angle for this pair of UTs (may be a null model – see INT-403-TSP-0001)
    - Constant-term OPD (differential OPD due to relay system and BCA paths)
- OPD offsets (elaborated below)

Astrometric quantities such as apparent place, sidereal time, and diurnal aberration are defined, for example, in the manual for the SLALIB software library at http://star-www.rl.ac.uk/star/docs/sun67.htx/sun67.html

We define the constant-term OPD as being the part of the Earth-rotation-independent differential OPD that does not change between re-calculations of the baseline solution. A baseline solution will be determined at most once per night.

Two much smaller offsets are added to the constant-term OPD by the DLCS:

- *Intra-night offset*: accounts for thermal effects during the night; changes on hour-to-minute timescales
- *Fringe tracker offset*: accounts for fringe motion due to atmospheric turbulence; changes on millisecond-to-second timescales

2.1 Observability of a target

We recommend that the slowly-changing parameters needed to calculate delay line trajectories (i.e. all those listed above bar the OPD offsets) are stored by the ICS, since they are needed for other purposes besides operating the delay lines. However, it is natural that the calculations themselves be performed within the DLCS, to avoid unnecessary load on the ICS (see next section).

Obviously, the DLCS must calculate (or be supplied with) the desired sidereal trajectories. However, knowledge of delay line sidereal trajectories is also required to determine whether a target is observable at a particular epoch (as is knowledge of the UT pointing limits). It is for this reason that we recommend that the *parameters* needed to calculate sidereal trajectories are managed by the ICS, rather than by the DLCS.

As an aside, calculation of sidereal trajectories to determine observability is the main function of interferometer observation planning software such as MSC's getCal. We expect that similar functionality will be provided for MROI, perhaps as part of the ICS.

2.2 Trajectory information flow

The precision required for trajectory calculations to operate the delay lines is much higher than that needed to determine observability. The required precision is quantified in the document "Timing Requirements for Control Loops", which derives the requirement that the trolley position must be calculated at 0.1 second intervals if a constant-velocity trajectory is assumed between these control points.

In the prototype DLCS, the calculation of the demanded trajectory from the above information is performed by the Workstation, slightly in advance of the calculated trajectory being used by the VME CPU to determine the OPD error signal.

The current UTC time, UT1-UTC and the longitude of the observatory are required to calculate the sidereal time. The geocentric position of the observatory is needed in order to calculate the diurnal aberration. We anticipate that these parameters, together with the baseline parameters and constant-term OPD for each delay line, would be stored by the ICS and accessed by the subsystem performing the trajectory calculation as required.

We anticipate that the ICS would be responsible for updating the baseline parameters based on measured fringe offsets.

The apparent place of the observing target is calculated from a catalogue position, for an epoch sufficiently close to the time of observation. We anticipate that the apparent place would be calculated by the ICS, since it is likely to be a parameter that must also be passed to the UT control system.

If we assume that the trajectory calculation is performed by the DLCS (our recommended implementation), the following commands from the ICS would be used to control the delay line trajectories:

Command	***Parameters***	***Note***
Track target (sidereal trajectory)	Apparent RA & dec	
Go to position	Position	Stops at commanded position
Query position	—	
Stop	—	At current position
Constant velocity	Velocity	Moves from current position
Go to datum	—	
Query OPD offset	—	OPD offset applies to all trajectory types
Set OPD offset	Offset	
Fringe search	Increment & interval	Increment OPD offset at specified time intervals
Apply offsets from Fringe Tracker	—	
Stop applying FT offsets	—	

The configuration parameters used in the trajectory calculation are as follows:

Configuration Parameter	***Note***
Observatory coordinates	
UT1-UTC	Available from International Earth Rotation and Reference Systems Service
Baseline parameters	Vector baselines and UT pathlength variations
Constant-term OPD	OPD offset is added to this by DLCS

The DLCS must provide information on whether and how well each delay line is following the demanded trajectory. This information would be used by the ICS in deciding when interferometric fringe data can be recorded, and is also needed for offline analysis of the fringe data.

Telemetry Stream	***Note***
OPD error	Mean error over e.g. 0.1s window
OPD jitter	Standard deviation of error over e.g. 0.1s window

3 Control Loop Parameters

There are various servo parameters associated with the OPD loop that may be varied. These parameters will be defined in more detail at a later date. It should not normally be necessary to alter the OPD loop parameters during operations.

The gains for the steering and shear loops may be adjustable – this will be decided when the loops have been implemented on the prototype. We do not anticipate that the gains will need to be altered during normal operations.

Command	***Parameters***	***Note***
Query OPD servo parameters	—	
Set OPD servo parameters	Parameter values	
Query steering gain	—	
Set steering gain	Gain value	
Query shear gain	—	
Set shear gain	Gain value	

4 Fiducials

Several of the control loops involve fiducials that can be set under software control, as follows.

4.1 OPD datum

A special mode of the OPD loop is used to drive the trolley precisely to the datum and then reset the metrology count. This mode is used at the start of the night and after any loss of metrology signal. The command to activate this mode is listed in Section 2.2.

4.2 Shear fiducial

Each shear sensor calculates the shear error signal as the difference between the measured shear and a fiducial position. The correct fiducial position would normally be determined by using the sensor to measure the shear over the full range of the delay line, and calculating the mean value on each axis. This would be a daytime procedure.

Command	***Parameters***	***Note***
Query shear fiducial	—	
Set shear fiducial	Fiducial X, Y	

Telemetry Stream	***Note***
Shear as function of trolley position	Could be constructed from shear(t) and position(t)