Calibration of the Dual-Recycled GEO600

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Dual-recycled GEO600

signal-recycling mirror added

North arm (600m)

East arm (600m)

North
General approach

• Undo the effects of any transfer functions from differential displacement to output voltage
  • optical transfer function
  • differential lock servo-loop

• Convert recovered differential displacement to strain
Simplified detector model

- High-power diode (Q)
- High-power diode (P)
- Quad diode (low-power)
- Split feedback Path

Differential displacement

Calibration signal

High-power diode (Q)
High-power diode (P)
calculate h(t) from here!
Low-power diode (P')
- Frequency dependent optical gain
  - different from power-recycled case (flat optical response)
  - time-varying overall gain – what about time-varying frequency response?

PR → DR
Measured optical response (S3I)

DC Gain: 5740
Pole f: 1225 Hz
Pole Q: 2.7
Zero f: 1400 Hz
Calibration Lines (S3I)

- Injected into ESD actuator using purpose built generator

G1:LSC_MID_CAL

G1:LSC_MID_EP-P_HP

Volts

Actuator

Optical

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Calibration Equation

\[ d(t) = F'_\text{opt} \left\{ P_{EP}(t) \right\} + F_{FB} \left\{ P_{EP}(t) \right\} \]

High-frequency (open-loop) correction – inverse optical response

Low-frequency (closed-loop) correction – response of feedback paths

\[ h(t) = \frac{d(t)}{1200} \]
System identification

- Recover parameters of optical response
- Form transfer function from calibration lines to detector output
- Fit model transfer function to measurements
- optimisation routine – hfit() - runs once per second
  - returns Pole freq, Pole Q, Zero freq, DC gain
  - gives $\chi^2$ measure of fit (see later)
Calibration Routine

System identification

Optical response correction

Loop-gain correction

\( h(t) \) production
Analysis of S3I data

- Optical response corrected with fixed frequency dependence – good assumption?
  - later done with varying frequency response
- What does the $\chi^2$ tell us?
- How good is the calibration?
Recovered optical parameters
Distribution of optical parameters

DC Optical Gain

- $\mu = 6033.1$
- $\sigma = 232.4$

Pole f

- $\mu = 1220.2$
- $\sigma = 14.1$

- $+1.1\%$

Pole Q

- $\mu = 2.7$
- $\sigma = 0.1$

- $+3.7\%$

Zero f

- $\mu = 1369.9$
- $\sigma = 33.1$

- $+2.4\%$
Optical response variations

Recovered responses taken every 5000 secs of the first week of S3

< +- 2°
$\chi^2$ triggers

- nominal $\chi^2 \sim 50$
- 591 triggers > 200 in 604,800 secs
Quality channel

- Quality channel contains information about data quality and detector status in 16 bits
  - Lock indicator
  - Maintenance time
  - $\chi^2$ threshold crossings
  - Extendable to more....
- Highest quality is 0

<table>
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<th>BIT</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>...</th>
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lock status

maintenance condition

$\chi^2$ threshold 1
$\chi^2$ threshold 2
$\chi^2$ threshold 3
$\chi^2$ threshold 4

GEO meeting – March, 2004
Calibrated $h(t)$
Summary

• Good so far...
  • calibration good to ~10% across most of the detection band
    • still dominated by calibration actuator
  • high confidence in parameter recovery
  • fast processing (4x real-time on my laptop)

• Where to go from here?
  • more validation
    • freq-domain comparisons, simulations (some done)
  • on-line updating of optical correction filters using estimated parameters – tried, but not tested fully
  • Include other quadrature (Q) in calibration process