LLO Calibration for S1 segments without calibration lines

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1 Introduction

During S1, some of the times when the LLO interferometer was in "Science mode", the calibration lines were not turned on for one reason or another. This document provides as many details as possible for these segments, with suggested calibrations to use, and some estimate of the errors associated with the suggestions.

2 Calibration lines

There are 144 "science segments" for L1, adding to a total of 170.17 hours. Lines are absent in the first 16 segments, and segments 70, 71, 72 and 77; adding to a total of 26.71 hrs (16% of the total time). Lines are missing in fragments of segments 17, 20, 26, 76, 98.

The normal method for the calibration versus time that we have used is to choose a standard calibration time, performed on Sept 06 22:53; measure the amplitude of the calibration line at 972.8 Hz at the same time when the calibration was performed; and then use the amplitude of the calibration line in other segments to get the relative change in gain of the sensing function, which we call α. The change in open loop gain is scaled by a factor $\alpha\beta$, where β is an overall gain change in the digital filters used in the control loops. The factor β was constant in any given locked segment, and it only changed a few, well documented, times during the S1 run.

3 Alternative calibrations

The relative amplitude of the sensing gain α is related to the alignment of the interferometer. If we plot a curve for each segment with the alignment function $P^2 = (\text{NPTRR} + \text{NPTRT}) * \text{SPOB}$, as shown in Fig1, we see that its
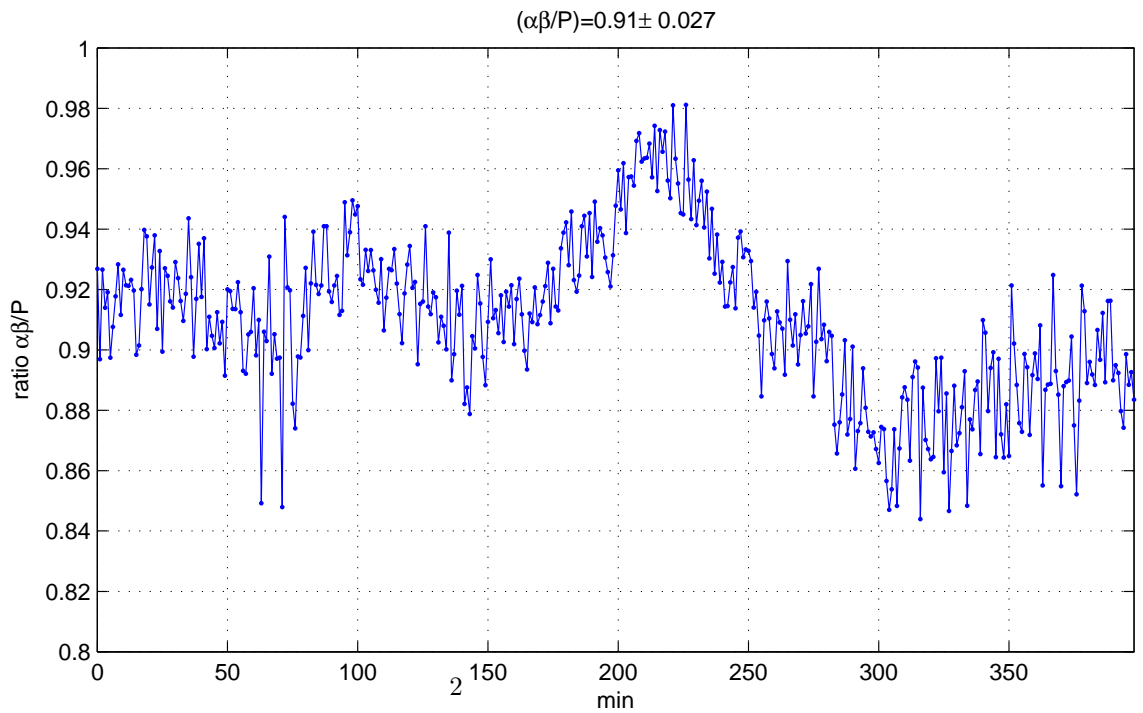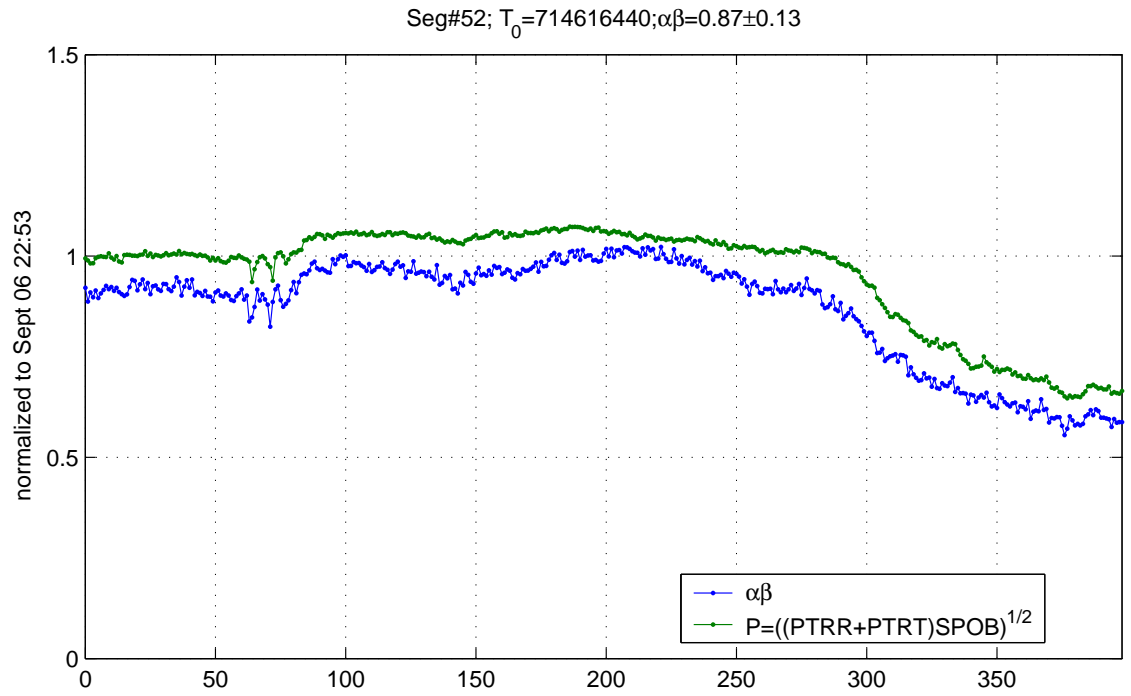
Figure 1: Fluctuations in alignment and gain during locked segment #52. In this segment, $\beta = 1$.

fluctuations follow the fluctuations in the calculated function $\alpha\beta$, whose changes are only due to changes in α.

We also see in Figure that there is a seemingly constant ratio between the alignment function $P(t)$ and the sensing gain $\alpha(t)$. For the segment in the figure, the variation of the ratio α/P within the segment is only 3%, while the variations in either the alignment function or the calibrated gain is 15%.

The ratio α/P, however, is different than one, so we cannot get the absolute value for the calibration from the alignment function. We plot in Figure 2 the values of the ratios $r = \alpha/P$ for each of the segments that had a calibration line, and a histogram of the values. We also show the value of β for the segments. From the histogram, there seems to be a double peak; the points in the lower peak are mostly the ones after segment #120, when β was changed significantly because we had more problems keeping the alignment than usual. (However, there was a similar change in β, in the other direction, at the beginning of the run, which did not seem to introduce similar systematic effects).

For the segments where the line was present some fraction of the time, we can measure the ratio $r = \alpha/P$ at the time where the lines were present, and use the function r/P at times when the lines were absent to obtain α.

For the segments where there are no calibration lines, we can assign them an average ratio α/P calculated from the rest of the segments, and then calculate α from the measured P. The average is $\bar{r} =< \alpha/P >= 0.84 \pm 0.09$ (this measurement excludes the points after segment #120 and the two obvious outliers with ratios larger than 1.2).

We made a few measurements of the open loop gain before, after and during S1, using swept sine excitations. The one made on Sept 06 is the one taken as the "standard".

Meast. Date (UTC)	β	α
Aug 24 08:18	1.08	0.65
Aug 25 04:52	0.77	0.85
Aug 25 10:18	0.77	0.75
Aug 26 23:49	1	0.80
Sept 06 23:02	1	1
Sept 09 02:17	1.42	0.63

The alignment function at the standard calibration time on Sept 6 (715388533), measured in the interval 715387980 - 715389120, was 606 ± 5 counts: this is the value to be used when normalizing power functions at other times. The earlier calibration on Aug 25 (714286333) had a alignment function for 714286400 - 714287300 equal to 579 ± 2 counts, or, normalized to the standard calibration, $P = 0.96 \pm .01$. This corresponds to a normalized ratio $r = \alpha/P = 0.85/0.96 = 0.89 \pm 0.05$ (the error assigned to measurements of α is 0.05). Calculating the ratio for the next two calibrations on Aug 25 10:18 and Aug 26, we get r=0.77 and 0.89, respectively. All these measurements agree well with the assumed average ratio $\bar{r} = 0.84 \pm 0.09$.
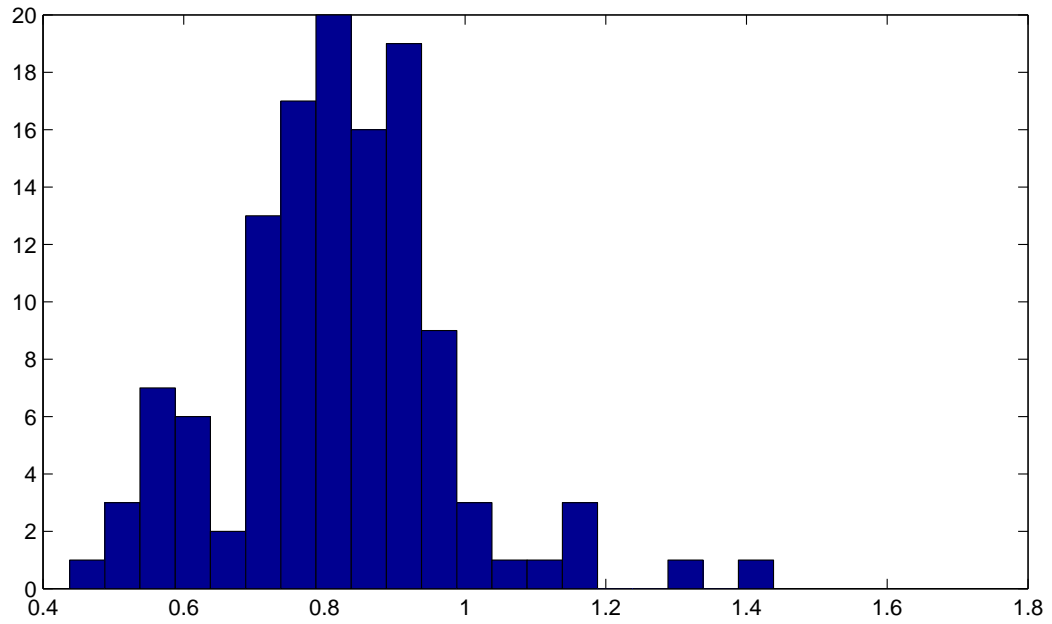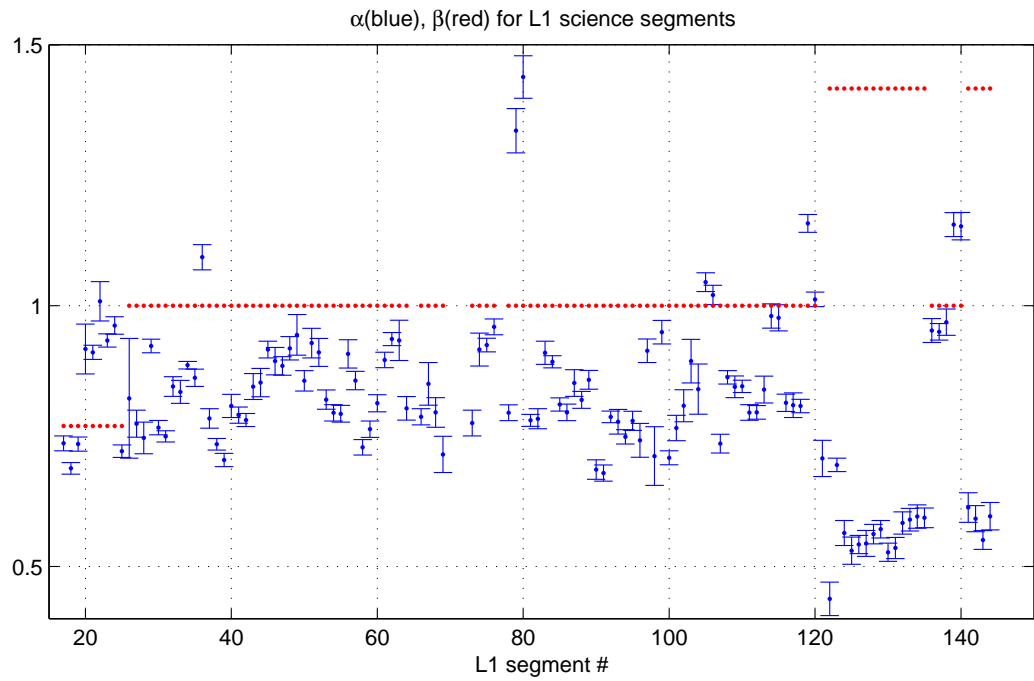
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Figure 2: Values of the ratio of calibration gain $\alpha\beta$ and the alignment function $P = \sqrt{(\text{NPTRR} + \text{NPTRT})\text{NSPOB}}$.   4
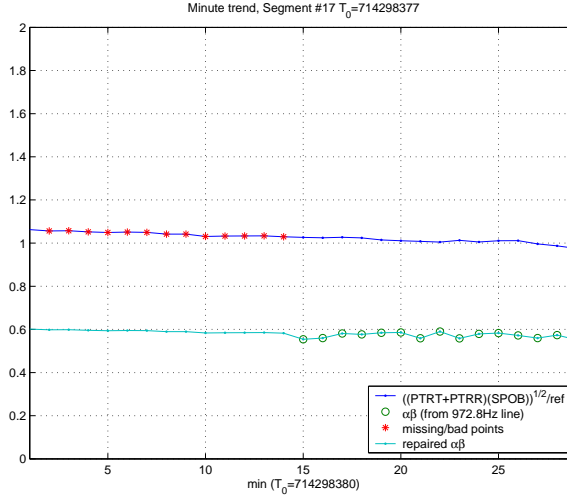
Figure 3: Repaired Science Segment

4 Results

4.1 Segments with lines

Five science segments had the calibration line present a fraction of the time; for these segments we calculate an average ratio $r = \alpha/P$ when the line is present, and use this average ratio for the minutes when the line was missing, or misreported because it was missing a fraction of the minute when the trend was calculated.

We plot in Figures 3-7 the results for the "repaired" calibration function $\alpha\beta$. The calibration information for these segments can be found in the file `RepairedSegWithLines.txt`, in the web page

www.phys.lsu.edu/faculty/gonzalez/S1Calibration/

4.2 Segments without lines

For segments #1-16, 70-72 and 77, we did not have calibration lines at any time during the segments. We then assume a ratio $\bar{r} = \alpha/P = 0.84 \pm 0.09$, calculate the alignment function divided by the reference value $P_{ref} = 606 \pm 5$ counts: $P = \sqrt{(NPTRR + NPTRT)NSPOB}/P_{ref}$, and then calculate $\alpha = \bar{r}P$. We assume a systematic error in the calibration of 11%. We plot in Figs 8,9,10,11 and 12 the results. The actual calibration information for these segments can be found in the file `RepairedSegWithoutLines.txt`, in the web page

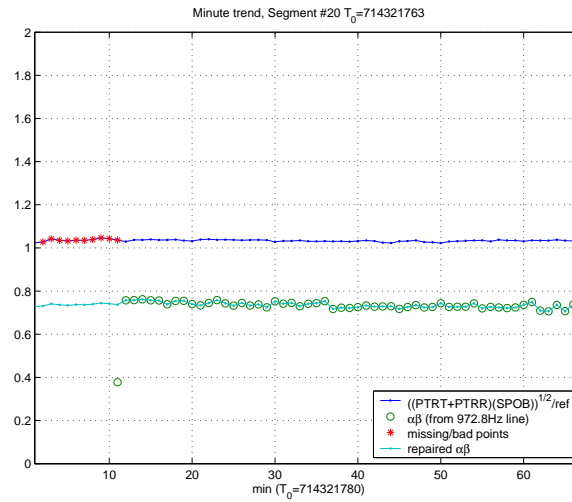www.phys.lsu.edu/faculty/gonzalez/S1Calibration/
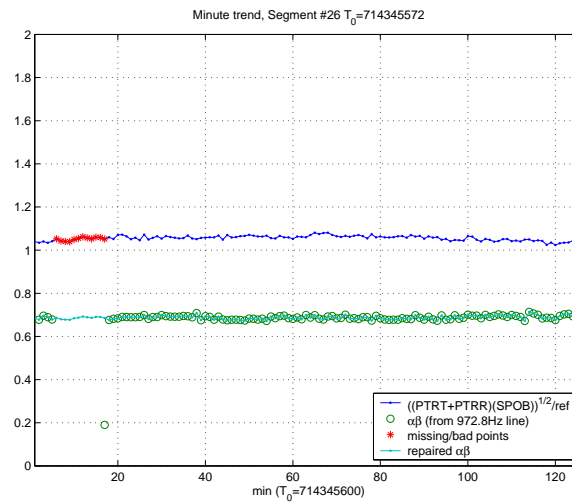
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Figure 4: Repaired Science Segment
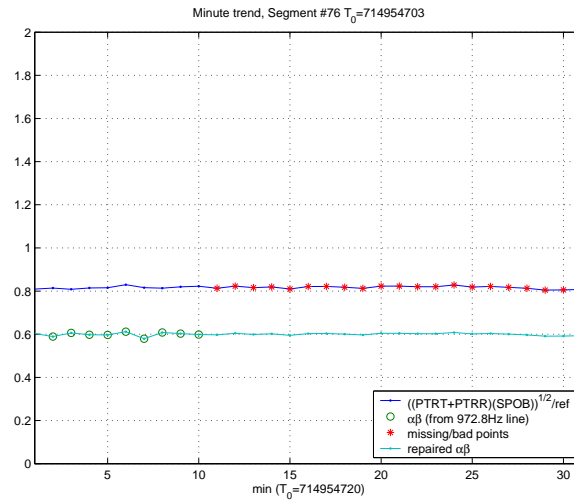

Figure 5: Repaired Science Segment

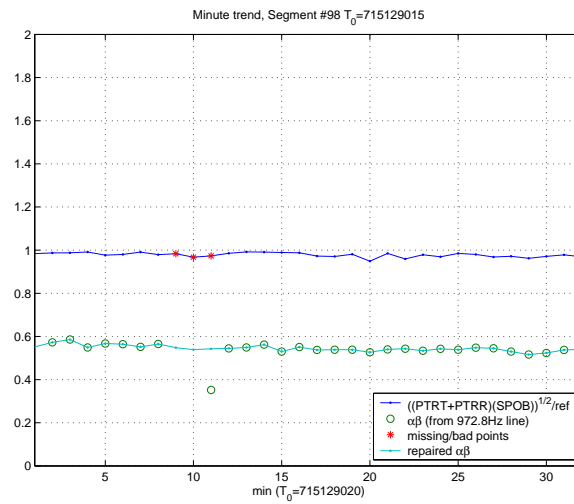Figure 6: Repaired Science Segment

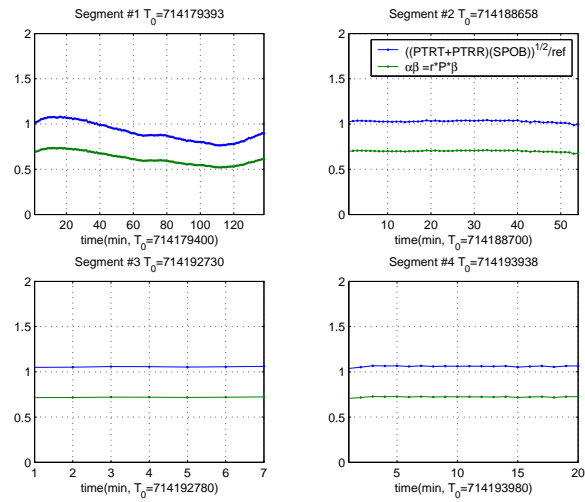
Figure 7: Repaired Science Segment
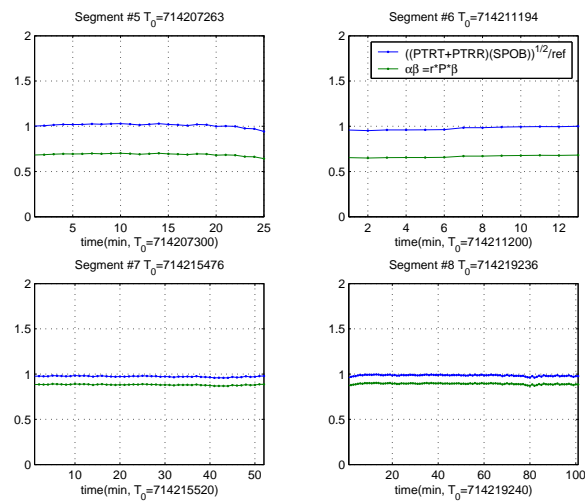
Figure 8: Repaired Science Segments
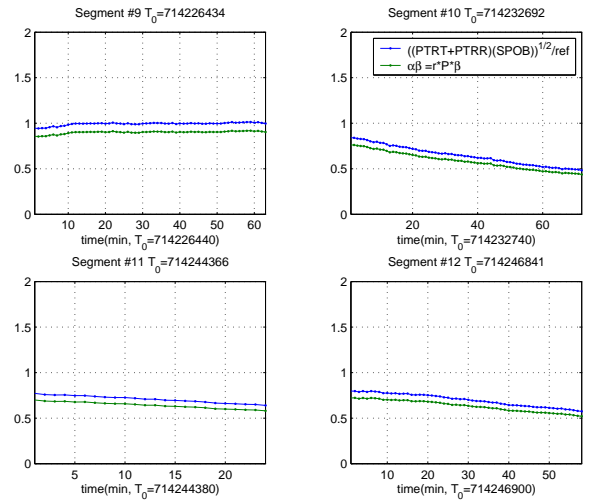

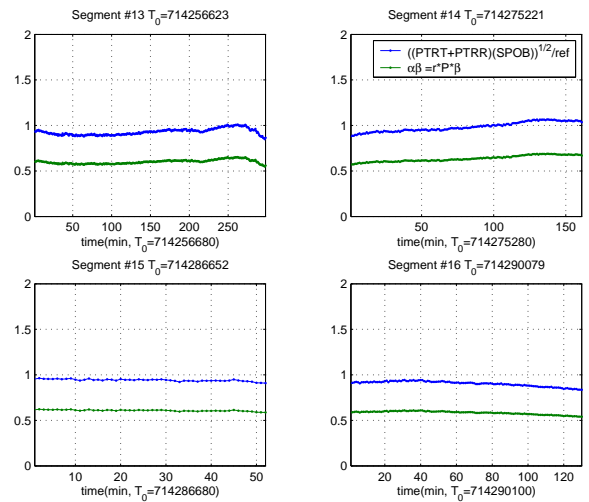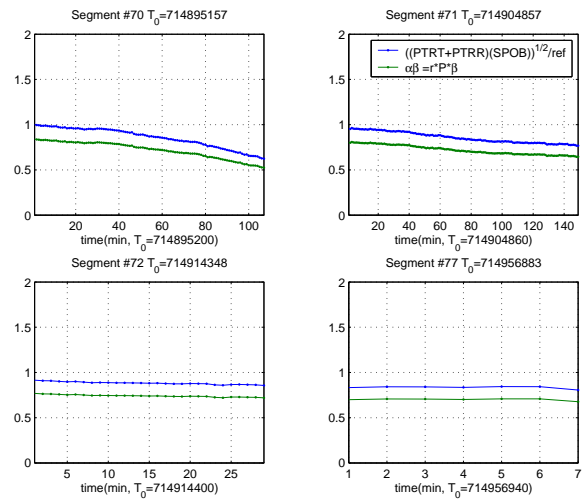Figure 9: Repaired Science Segments

Figure 10: Repaired Science Segments

Figure 11: Repaired Science Segments

Figure 12: Repaired Science Segments