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Shutter repairs and updated fibre conversion at Carnarvon in 2019 February

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Abstract

Carnarvon was offline due to a shutter motor failure, and a computer failure. The shutter motor and reduction gearbox was replaced with the spare from the on-site shipping container. A new computer was installed. Further work was completed on the Jabba fibre-conversion to resolve some ongoing issues and return the instrument performance and data quality to expected levels.

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1 Introduction

Jabba was converted from direct sunlight to fibre-feed in 2018 April [1], but the weather towards the end of that visit was poor meaning that little testing could be completed. Following the conversion, several issues with the data quality were identified including low frequency drifts/steps and increased high frequency noise. Additionally, less than a month after the visit the shutter motor failed, shortly followed by the computer, taking the whole site offline.

Steven Hale visited Carnarvon from 2019 January 31 to February 11. The purpose of this visit was to replace the shutter motor and the computer, and to make additional modifications to the Jabba fibre-conversion to improve the data quality. Section 2 first discusses the repairs to the shutter motor and the computer, and some general maintenance required to bring the site back online. Section 3 then discusses the further changes to Jabba and the configuration updates that were required to restore the data quality to that of previous years.

2 Site Maintenance

2.1 Shutter Motor

Shortly after the previous site visit, the shutter motor failed on 2018 May 3. The spare shutter motor and reduction gearbox were installed during this visit on 2019 February 1 and confirmed operational. There is no longer any stock of spare motors or gearboxes at Carnarvon or Birmingham.

2.2 Rain Detector

The rain detector was tested and confirmed positive reaction to water. The weather module still occasionally suffers from false rain trips, and the cause of these remain under investigation.

2.3 Computer

Shortly after the previous site visit, the computer failed on 2018 July 16. A new power supply was installed on 2018 October 2 but the computer would no longer boot. It was suspected that one or both of the hard disks had been damaged during the power supply failure.

On arrival during this site visit it was confirmed on 2019 February 1 that the computer did not boot, it halted at the Dracut emergency shell with the error that it was unable to mount /mnt/sysimage. The problem was a corrupt XFS filesystem. After running XFS repair on all filesystems the issues were resolved and the system would boot. This problem rarely, if ever, happened during power failures when using the ext4 filesystem and so it is recommended to return to using ext4 on future site PCs rather than the new RHEL/CentOS/Fedora default of XFS. One of the hard disks could not be detected by the BIOS and would eventually timeout, but this was related to a partially dislodged SATA connector.

Despite the original computer returning to normal operation, a new PC was installed on 2019 February 2. The existing DIO and RS232 cards were transferred over from the old system. The new PC is configured with CentOS release 7.6.1810 and kernel 3.10.0-957.1.3. The DIO card device driver (the gnat) is confirmed to work with this kernel release, but has not yet been tested on anything newer.

2.4 UPS

On the previous site visit, it was found that the UPS provided zero seconds of backup power. A new Upsonic Power ESAT-15 UPS was ordered, but it did not arrive before the end of the visit. On arrival during this visit, the new UPS was found unpacked and powered but with none of the outputs connected. The ESAT-15 was installed on 2019 February 2, and tested to ensure it could close the dome from fully open at least once with the utility supply disconnected.

2.5 RCDs

The three RCDs on the dome three-phase incoming supply were tested via their built-in test buttons on 2019 February 2 and confirmed operational.

3 Jabba Optimisation

3.1 Optics

The original Jabba double-field spectrometer optical configuration is shown in Figure 1. The lenses, labelled L1 through L6, are defined in Table 1. During the site visit in 2018 April [1], both L1, L2, and the filters were removed, and the fibre output mounted at the shared focal plane between the original L1 and L2 lenses. The new L2 fibre collimating lens is a Thorlabs AC254-030-B-ML with focal length of 30 mm and diameter 25.4 mm, the same lens as used at the input of the fibre.

Lens L3 originally produced a solar image on L4 immediately before the first magnet assembly. L4 is a Fabry lens intended to change the imaging of the system such that the image formed in the vapour cell is of the objective aperture rather than the Sun. The Fabry lens partially scrambles the solar image and reduces the effect of so-called Doppler Imaging inside the vapour cell. Whilst the image scrambling effect is no longer required when using an image-scrambling optical fibre, these two lenses were maintained as originally installed in order to minimise the changes to the instrument. Unfortunately it was later found that the data quality had deteriorated due to a lower signal-to-noise (i.e., cell hot-to-cold) ratio, and this was believed to be caused by an increase in the non-resonantly scattered light from within the cell ovens. The change in initial collimation optics produces a beam that has a slightly larger diameter than the original design, and this may have been causing the increased illumination of the inside of the ovens.

On this visit, both L3 and L4 were removed. Lens L4 was replaced by a Thorlabs AC254-100-B-ML lens with focal length of 100 mm and diameter 25.4 mm, which focuses the collimated beam into the vapour cell and ensures that the beam is sufficiently converged to clear the magnet entrance aperture. The effect of the Fabry lens is no longer required since image scrambling is achieved via the optical fibre. Only lens L5 between the two ovens is now original to the design of Jabba. Lens L6 is no longer present since the transmission monitor was not reinstalled following the 2009 spectrometer refit [2]. The beam collimation, focus, and alignment was checked by removing the 1.5 nm interference filter and both the ovens. A 770 nm fibre-coupled LED was used to provide a beam through the instrument, which could be viewed and optimised. This same optical configuration is in use successfully with the fibre-conversion of Klaus at Mount Wilson [3], and so no further issues are expected with the optical design.

3.2 Oven Temperature

The oven temperatures and hot-to-cold ratios were checked both before and after installation of the new optics. When using a fibre-coupled 770 nm LED as a light source, the initial hot-to-cold ratios were 4.1 and 4.5 for forward starboard and forward port, and 1.5 and 2.3 for aft starboard and aft port. These are higher ratios than produced from sunlight, since the LED does not have the 770 nm absorption line present and so the results are similar to what would be achieved if measuring the solar continuum. As expected, the aft cell is poor due to high cold counts.

After replacing lenses L3 and L4, the hot-to-cold ratios changed to 4.2 and 4.7 for forward starboard and forward port, and 1.6 and 2.2 for aft starboard and aft port. These results show a slight improvement for the forward cell, and little change for the aft cell which still suffers from high cold counts. It is not clear what is causing the ongoing problems with the aft cell, or why the values show such a large difference between starboard and port detectors.

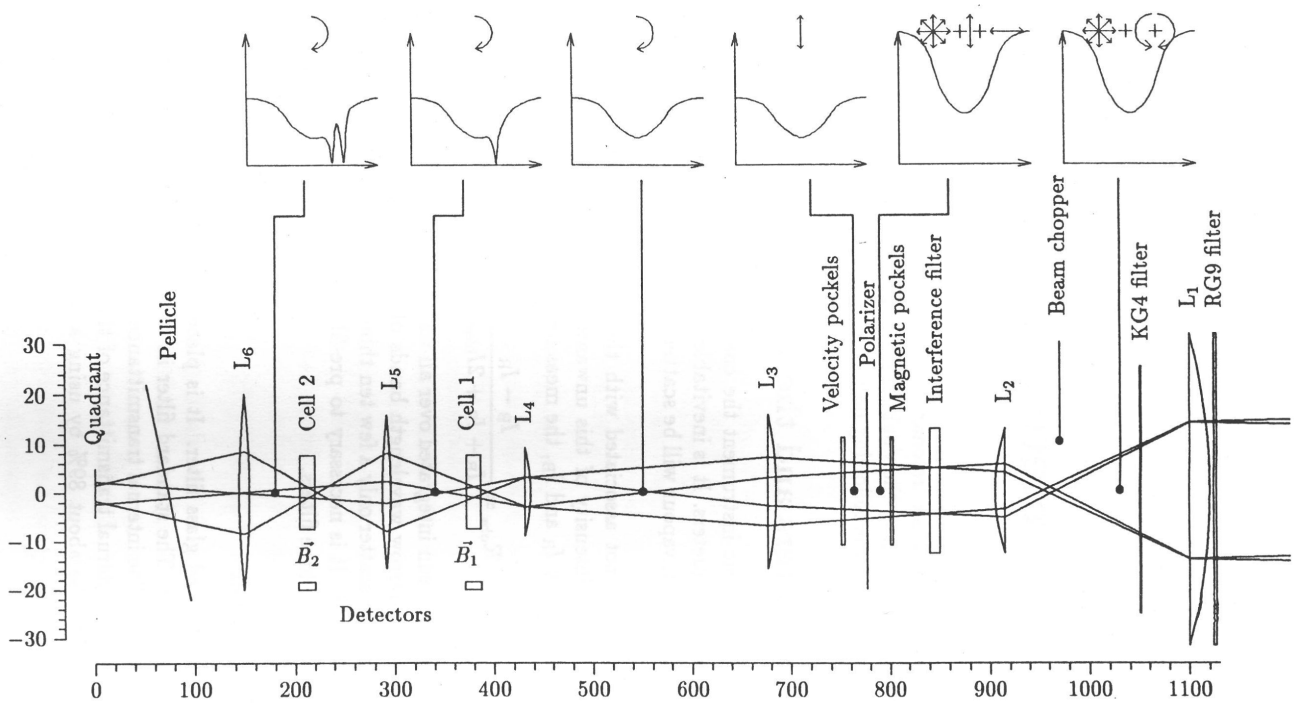


Figure 1: The Jabba double-field spectrometer optical configuration. Dimensions are in millimetres. The spectral intensity and polarisation state in the vicinity of the incident Fraunhofer line is shown at various locations along the optical path. The lenses are defined in Table 1. Reproduced from Lewis (1996) [4].

Table 1: The Jabba double-field spectrometer lenses. Reproduced from Lewis (1996) [4].

Lens	f (mm)	ϕ (mm)	Manufacturer	Part Number
1	150	63	Spindler & Hoyer	32 2228
2	50.8	25.4	Newport	PAC040
3	250	31.5	Spindler & Hoyer	32 2272
4	50	18	Spindler & Hoyer	32 2265
5	40	31.5	Spindler & Hoyer	31 1339
6	50	40	Spindler & Hoyer	31 1340
Detectors	20	21	Comar	20AF21

A heating curve to optimise the temperature set-point for both cells was produced on February 9. The results are shown in Figure 2. The optimum cell stem temperature was selected as 98 °C. The cell cube/top temperature was defined at the standard 20 °C above the stem temperature, resulting in a set-point of 118 °C. At these temperatures the hot-to-cold ratios achieved with sunlight were 2.5 and 2.8 for forward starboard and forward port, and 1.6 and 2.2 for aft starboard and aft port. The values from the forward cell have decreased to 60 % of that when using the LED, and this is about the reduction expected due to the depth of the solar absorption line. Both the cells show low hot-to-cold ratios suggesting that there is little potassium remaining in the cells, and they will likely need to be replaced soon. The cells were not replaced on this visit since very few spares are available in HiROS stock, and so replacements are restricted to only when absolutely necessary.

When Jabba was reinstalled in 2009 September, BTR323 shows the hot-to-cold ratios were 3.8 and 3.4 for forward starboard and forward port, and 2.3 and 2.9 for aft starboard and aft port [5]. The hot-to-cold ratios from Jabba have never been as high as some instruments at other

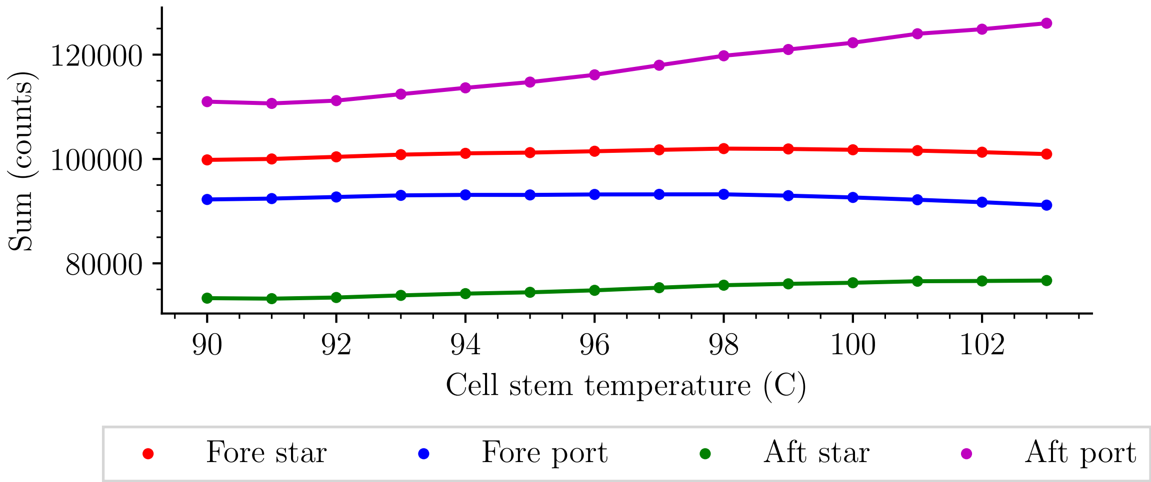


Figure 2: Oven stem temperature scan for both forward and aft cells. The optimum set-point was selected as 98 °C for the stem, and 118 °C for the cube/top.

sites even when the vapour cells were new. Recent work at Las Campanas where a new vapour cell was installed in Hannibal resulted in a hot-to-cold ratio of 14, which is predominantly due to the style of oven in that instrument having exceptionally good control of the non-resonantly scattered light.

3.3 Guiding

The guiding performance was measured during a site visit in 2016 August and found to have a FWHM of about $\pm 8''$ [6], which is more than sufficient to maintain an image of the Sun on the end of the fibre. The guiding showed a drift of about a third of a degree between sunrise and sunset, which was believed to be due to flexure of the mount itself between the guider telescope and Jabba where the camera was attached. However on this visit it was noticed that the fibre alignment does appear to show a variable offset throughout the day, even though Jabba and its heavy magnets are no longer on the mount, and this movement could be contributing to the low frequency issues if the drift is large enough to cause vignetting at the edge of the fibre.

The fibre input was aligned on the mount during the initial installation in 2018 April [1]. On this visit, some mechanical adjustments were made and another guider scan completed. The results are shown in Figures 3 and 4. These results are not as clean as from the last visit due to slight haze and occasional cloud. The final micrometer values were selected as 9.0 mm in RA and 3.25 mm in declination. The scan was performed near solar noon to ensure that any guiding drift should be symmetric about the centre of the fibre core and so minimise the chance of vignetting towards the edge. It is interesting to note in Figure 3 that the ratio begins to increase again as the solar image drifts far off the edge of the fibre, below a micrometer setting of 5.0 mm, and this could be another cause of low frequency offsets in the ratio. Perhaps a lens hood should be installed to limit the off-axis field-of-view.

3.4 Magnetic Pockels Cell

Jabba has two Pockels cells. The magnetic Pockels cell is L13, and the velocity Pockels cell is L14. During diagnostic work in 2016 August, L14 was removed and L13 moved from the magnetic

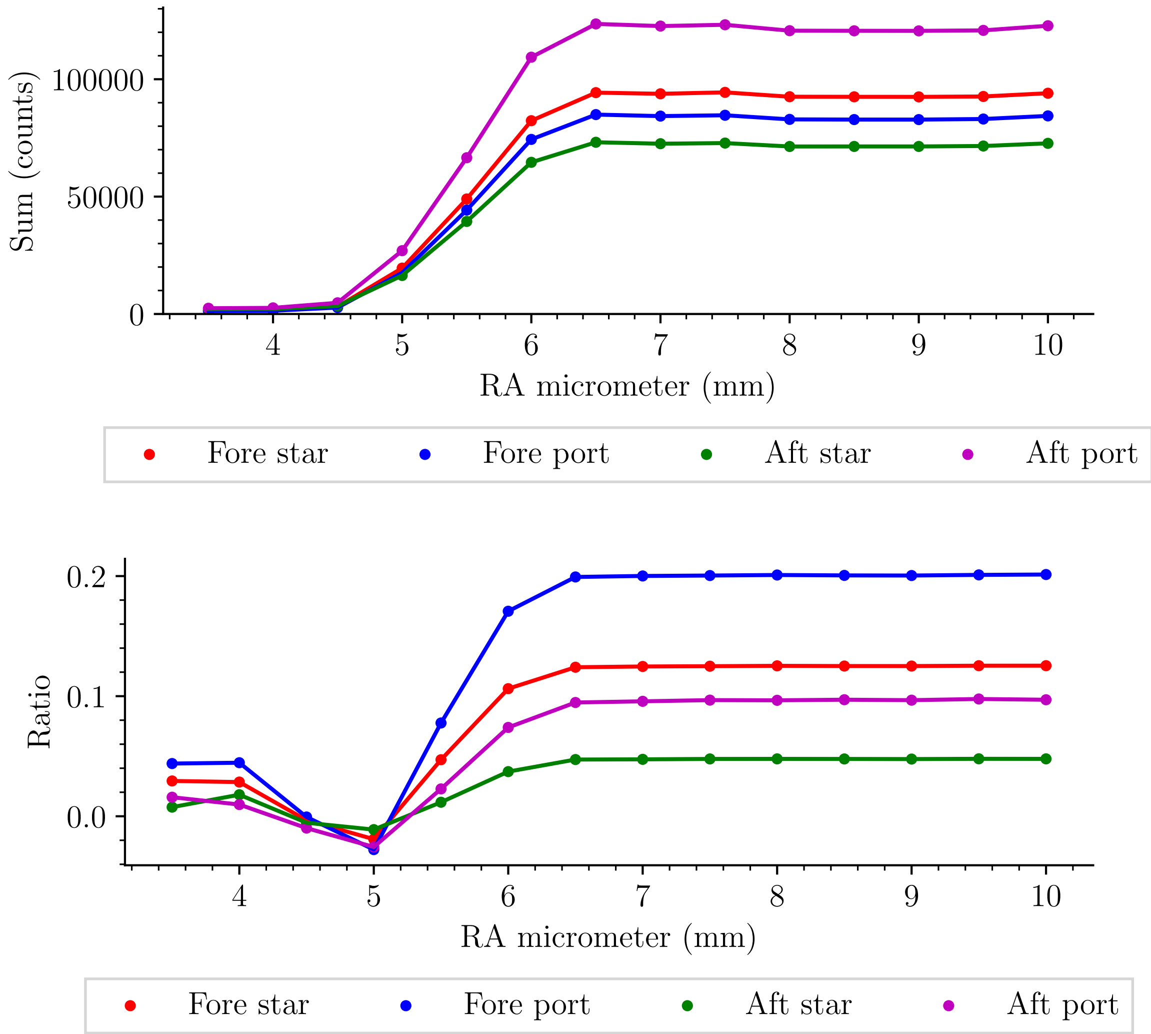
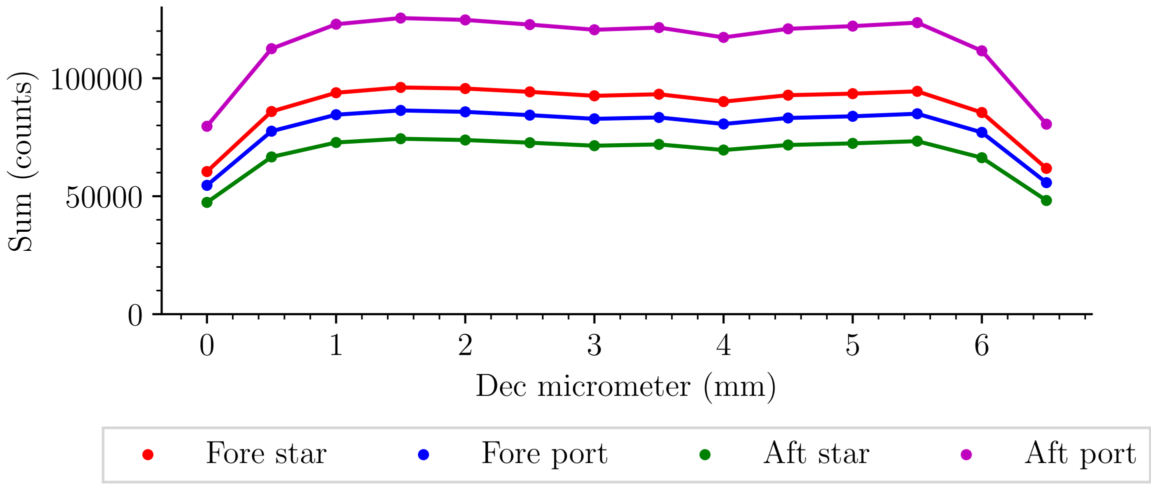


Figure 3: RA guider micrometer scan. 1 mm of micrometer travel is approximately 0.3° change in angle. The final setting was selected as 9.0 mm.

position to the velocity position [6]. Later, in 2018 April, Jabba was converted to fibre-feed and the two Pockels cells restored to their original positions [1]. However, this was a mistake since the fibre-feed does not maintain solar polarisation information and so any solar mean magnetic field data is lost. On this visit, L13 was removed again and returned to Birmingham. Jabba no longer captures solar magnetic data. The last magnetic data available from Jabba was prior to the site visit in 2016 August.

3.5 Polarisation Mixing

The existing counter configuration is causing mixing between each polarisation phase. When Jabba was returned to Carnarvon in 2009 [5], new digital counters were also commissioned for the first time. A default configuration was used which was believed to be similar to the original counters [7, 8], with a "front porch" of 0.5 ms (the time delay between commanding a polarisation state switch and counting recommencing), and a data acquisition time per phase of 5 ms. These values produce a switching rate for the velocity Pockels cell of 90.9 Hz and for the magnetic Pockels cell of 45.45 Hz. The total acquisition time (i.e., actual counting time) in each 4 s period is 3.4 s resulting in 15 % dead-time in each sample.



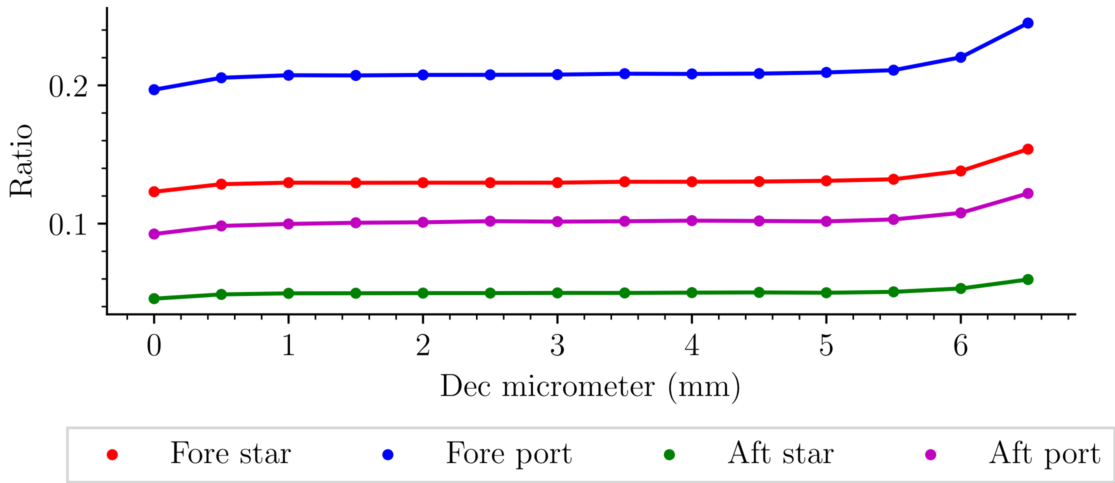


Figure 4: Declination guider micrometer scan. 1 mm of micrometer travel is approximately 0.27° change in angle. The final setting was selected as 3.25 mm.

Recent simulations of the Jabba scattering detector performance has shown that due to the high-gain / low-bandwidth of the circuit it takes about 2 ms to 4 ms to pass a transient signal (i.e., during a polarisation state change) depending on what is considered to be "complete". For a 10 % to 90 % transition the switching time is about 2.5 ms. When using a 0.5 ms front porch the polarisation states become mixed since the detectors are barely halfway towards seeing the new polarisation state at the time when counting restarts. This polarisation mixing could be the cause of low-frequency issues in the data, and the gain/offset differences in sensitivity between port and starboard detectors. On February 8 the front porch was briefly increased to 2 ms and the ratios from the forward port and starboard detectors did indeed move closer together.

Before making a permanent change to the counter configuration, other issues need to be considered. If the front porch is increased to 2.5 ms, then the data acquisition time per phase must be reduced to 3 ms if we wish to maintain the same 90.9 Hz switching rate. However, this increases the dead-time to 49 % and so reduces the statistical precision of the mean measured in each 4 s sample. If we allow the acquisition time to increase to 8 ms per phase then the dead-time rises to only 25.6 % at the expense of reducing the velocity switching rate to 47.6 Hz and the magnetic switching rate to 23.8 Hz. Noise from atmospheric scintillation reaches −3 dB at about 5 Hz and −10 dB at about 25 Hz, and so this reduction in switching rate should have no detrimental effects on atmospheric noise level.

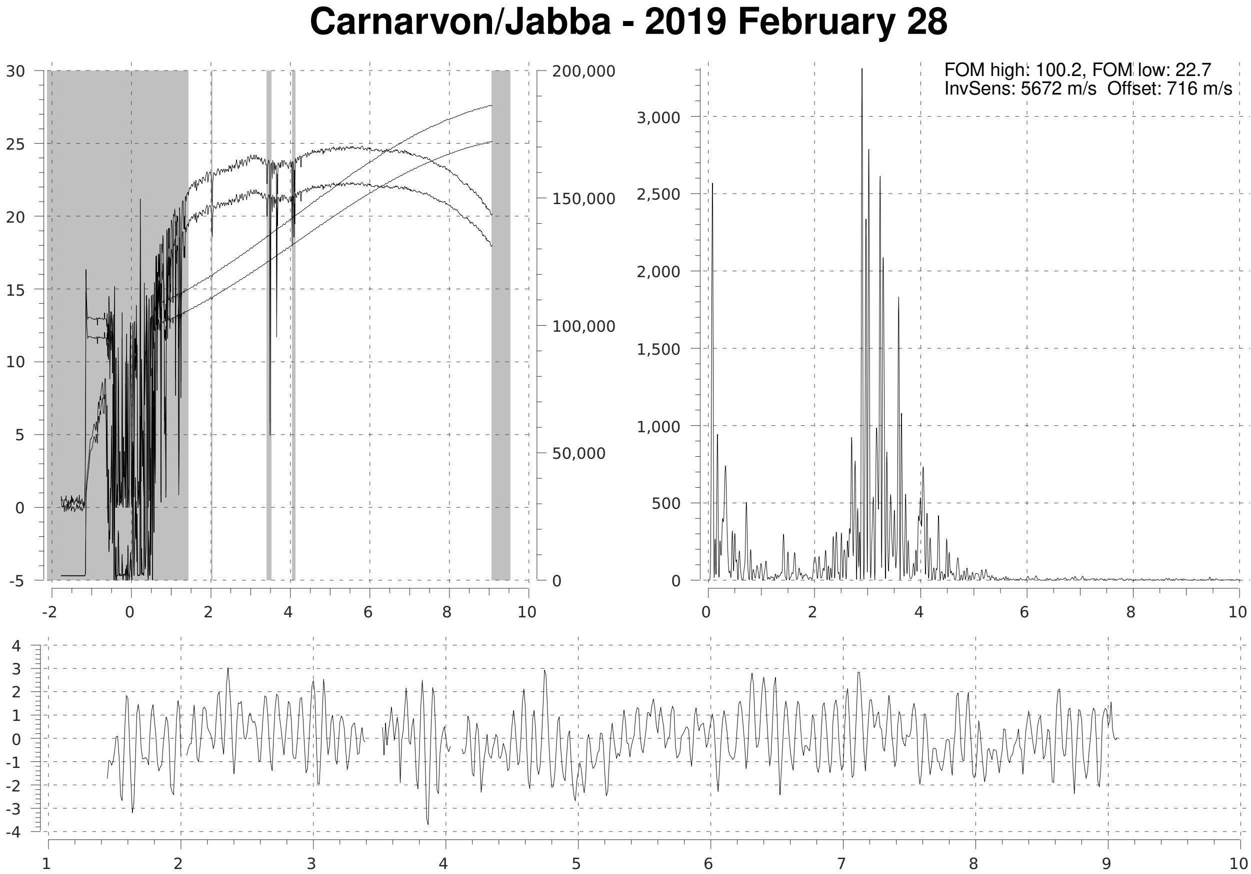


Figure 5: Data from Jabba with the counters reconfigured to use a 2.5 ms front porch and 47.6 Hz switching rate. The low frequency drifts have been almost completely removed, and the white noise visible at high frequency also shows a noticeable improvement.

Shortly after this site visit, the above changes were made to the counter configuration on February 27. Figure 5 shows data from February 28. The weather is rather hazy/dusty and so the results are not ideal, but the low frequency issues have been almost completely resolved and there is a noticeable improvement at high frequency. The ratios from the forward port and starboard detectors now show similar sensitivity, and so this resolves a problem that has been observed since 2009 [5]. However, the calibration inverse sensitivity is still low at $5.6\,\mathrm{km\,s^{-1}}$ rather than the typical expected $3\,\mathrm{km\,s^{-1}}$, and the reason for this is still under investigation.

The weather in Carnarvon following this configuration change has been poor, however the data so far do at least now appear as good as before the fibre conversion. The polarisation mixing issue will have existed since Jabba was reinstalled in 2009. It is not clear why the problem is more pronounced with the fibre feed than with direct sunlight, or what impact the problem has had on the historic data.

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