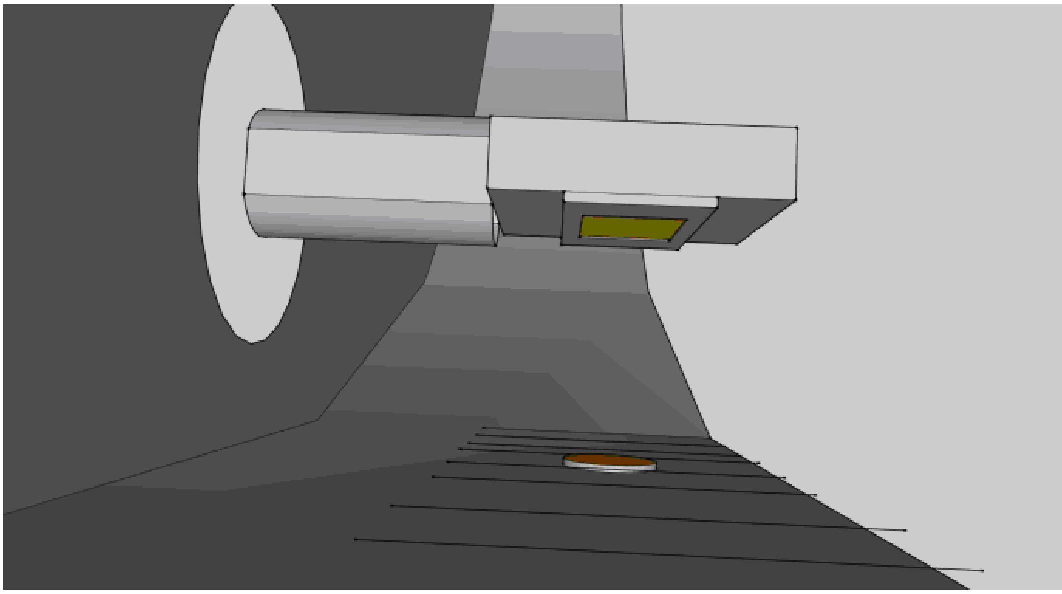
December 2011
Anders Ridley-Smith and Nick Ritchie

Encoder Alignment for Keck Telescopes to Reduce Interpolator Error

Introduction

This document outlines the method for adjusting the alignment of a single encoder read head in relation to the encoder tape to reduce interpolator error and thus improve the performance of the elevation and azimuth drives. It is to be followed if errors or inaccuracies in the operation of elevation or azimuth are noticed, as is indicated by events such as fatal following errors or warnings.



Notes

This procedure deals with sensitive and fragile equipment (the encoder read heads) that can become damaged easily if proper care is not taken. Take the time to read the procedure and reach an adequate level of understanding before proceeding with the task.

Material Required

For the procedure to be carried out, the following are needed:

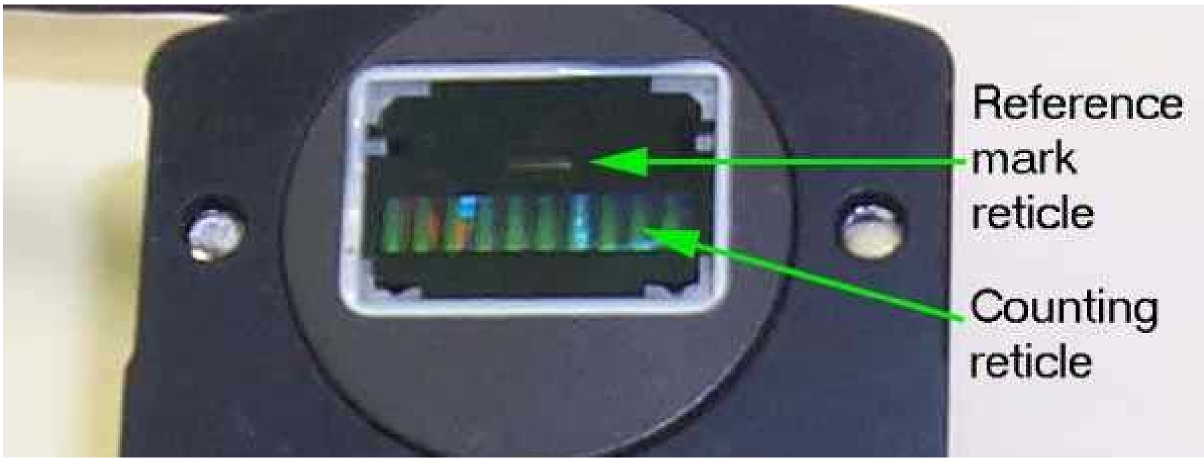
- Heidenhain PWM8 or similar
- 2 x BNC cables
- Digital Oscilloscope
- Allen keys
- 2 x Heidenhain proprietary encoder cables (should be with PWM 8)

Conceptualisation

To fully understand the following procedure, it is important to first think about:

- The layout of the encoder head in relation to the engraved tape,
- The meaning of the various signals obtained and,
- How various adjustments along or around different axes will affect the obtained signals.

The encoder head consists of both a counting reticule and a reference mark reticule which "observe" their respective markings on the encoder tape. The encoder counts are obtained by the regular engravings that pass the counting reticule whilst less regular C-Reference marks pass the reference mark reticule.



The signal for an optical encoder is obtained by the transmission and reception of light over the engraved markings on the encoder tape. The physical distance of the encoder head from the tape will affect how strong the received signal is due to focal length effects, as will be discussed later.

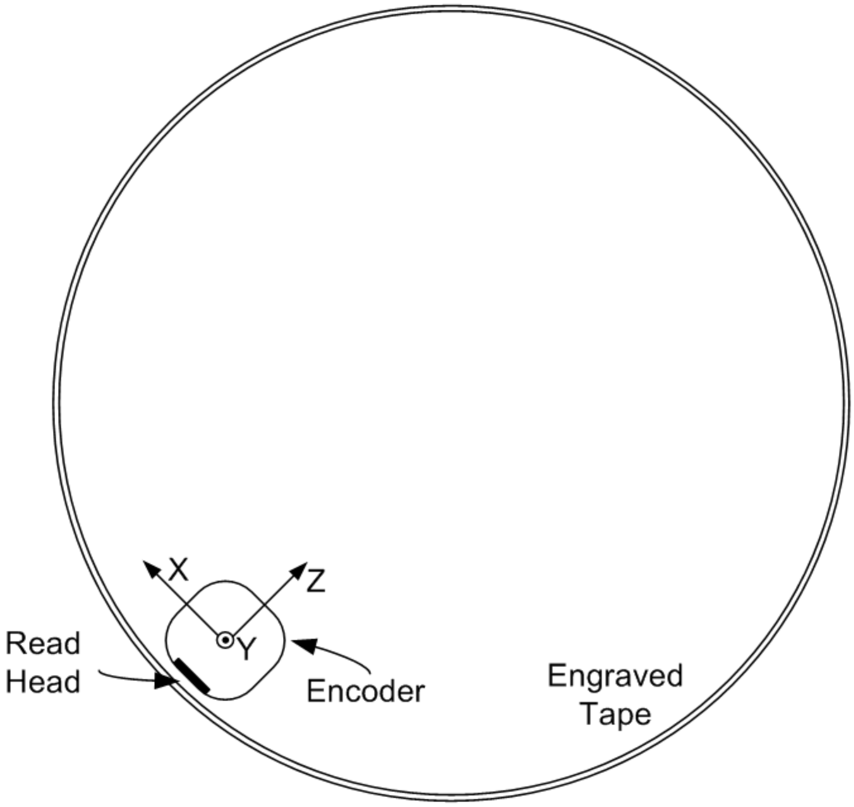
For accuracy, the counting reticule consists of two separate receivers that will receive a signal with a phase shift of 90 degrees in the ideal case. For this reason, we have three signals of interest:

- The first counting receiver pulse (TV1)
- The second counting receiver pulse (TV2)
- The C-Reference pulse

In the ideal case, the C reference pulse (henceforth Cref) will occur halfway between a pulse from TV1 and TV2. As such, by summing the TV1 and TV2 signals, the Cref Pulse should occur in phase with this new signal as will be discussed later.

There are two quantities that we would like to optimise in this procedure to ensure as close to ideal operation of the encoders. These are the phase angle between TV1 and TV2 (desired as close to 90 degrees as possible) and the alignment of the Cref pulse with the middle of the TV1 and TV2 pulses. We will now discuss how various movements and adjustments will modify these variables.

Although layman terminology such as to tilt “forward” or “away” could be defined and used in the following procedure, axis notation helps to remove ambiguities. As such, the axis system describing the read head relative to the encoder tape is established as follows:



Here the important thing to note is that the direction of the x-axis is always in the clockwise direction when looking at the encoder ring from an outer side.

From this axes definition, note that the two key words “translate” and “rotate” mean along or around an axes respectively.

The essence of the following procedure is to make fine adjustments along or around the three fixed-body axes to both minimise the phase error (offset from 90 degrees) between receiver one (TV1) and receiver two (TV2) and to minimise the phase error between a Cref pulse and a counter pulse.

Equipment Overview

The two key pieces of equipment needed to measure the alignment of the encoder head are the Heidenhain PWM8 and a digital oscilloscope.

PWM 8

The PWM8 captures the pulses from the encoder head (Cref, TV1 and TV2) and displays various output to describe them. The attributes of most interest to the user are the bars displays for the on-off error (Displayed as “TV1” and “TV2”) and the phase error for TV1 and TV2 (displayed as “PHA”).

The on-off error, outputted as an angular value on the bar graph, describes the inconsistency between the time that the encoder receives zero and the time it receives one (i.e. reflects off an engraving or the absence of). The total period (on and off) is given an value of 360 degrees. Thus an error of +10 degrees means that it receives an on signal for 190/360 of the time and an off signal for 170/360 of the time. See the PWM 8 User Manual for more detail. This quantity is not of much focus but should be kept relatively low (Less than 10 degrees).

The phase error is of more importance to us and describes the deviation of the pulses on receiver one and two (TV1 and TV2) from the ideal, which is a 90 degree phase offset. This value needs to be monitored and adjusted to below at least 20 degrees. Aim for less than 10 degrees.

Oscilloscope

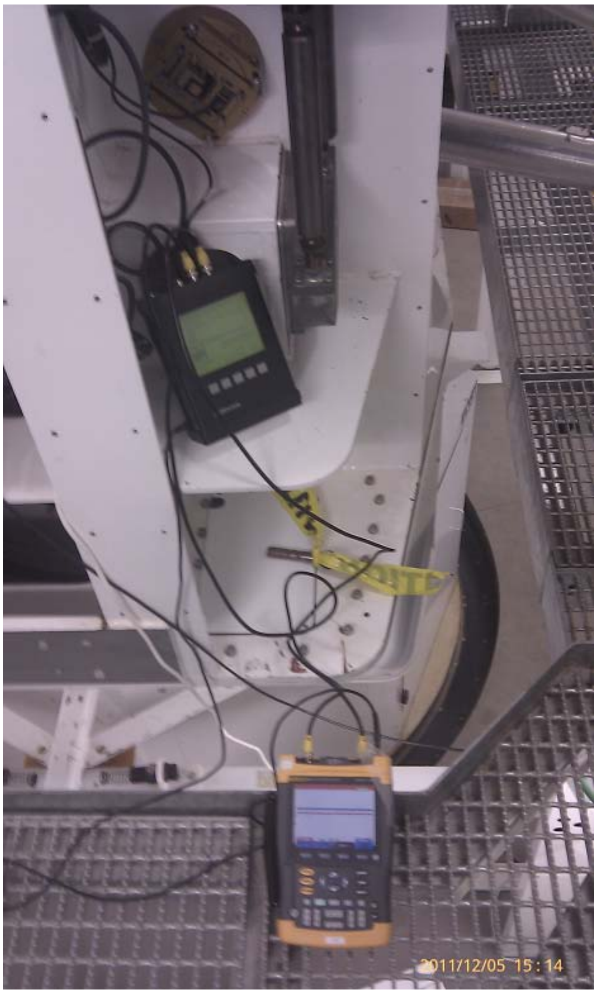
The use of the oscilloscope is important in determining the phase offset between Cref and the summed receiver pulses (TV1 + TV2). By outputting these two signals to the scope, adjustments can be made to attempt to get these signals as in-phase as possible. In-phase implies that the “valley” of the Cref signal (it is active low) lines up with the valley of the TV1 + TV2 signal.

Procedure

1. Begin by locating the positions of all encoders and verifying adequate access to the adjustment screws of each of them.

2. Ensure the telescope is not currently in motion and thus requiring the information from the encoder counts.

3. Complete the following cable setup
    a. Unplug the encoder cable from the interpolator (box device) and plug into the input jack of the Heidenhain PWM 8.
    b. Plug another encoder cable from the PWM 8 output to the interpolator. The PWM 8 is now an “in series” connection between the encoder and the interpolator and thus normal operation and telescope control can be carried out.
    c. Plug a BNC cable from PWM 8 channel A to the oscilloscope channel A.
    d. Plug a BNC cable from PWM 8 channel B to the oscilloscope channel B.



4. Power on both the Heidenhain PWM 8 and the oscilloscope.

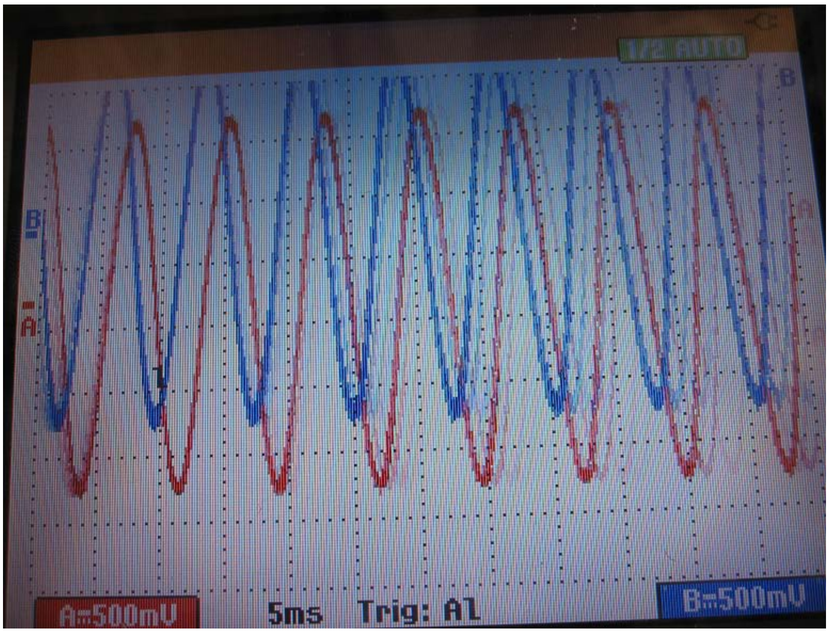
5. Configure the Heidenhain PWM 8 to output TV1 on BNC A and TV2 on BNC B. The TV1 and TV2 signals will be labelled as Ue1 and Ue2 respectively whilst the Cref signal is labelled as Ue0 on the PWM 8.

6. Configure the oscilloscope to DC coupling, high impedance, 0.5V per division and a timescale that allows 2 or more wavelengths per display. Leave triggering as automatic for the time being.

7. We are now ready to move the telescope in the azimuth or elevation direction to observe the pulse waveform produced by the encoder. This can be done by:
    a. Putting the telescope in automatic tracking mode on a selected star. If this is done, select a bias rate of about 6-8 arcmin/sec to ensure regular Cref pulses. Or,
    b. Disabling telescope control to allow manual movement of the telescope around its axes at a desired rate.

8. By moving the telescope with either of the above methods, observe the two waveforms produced on the oscilloscope. They should be sine waves of

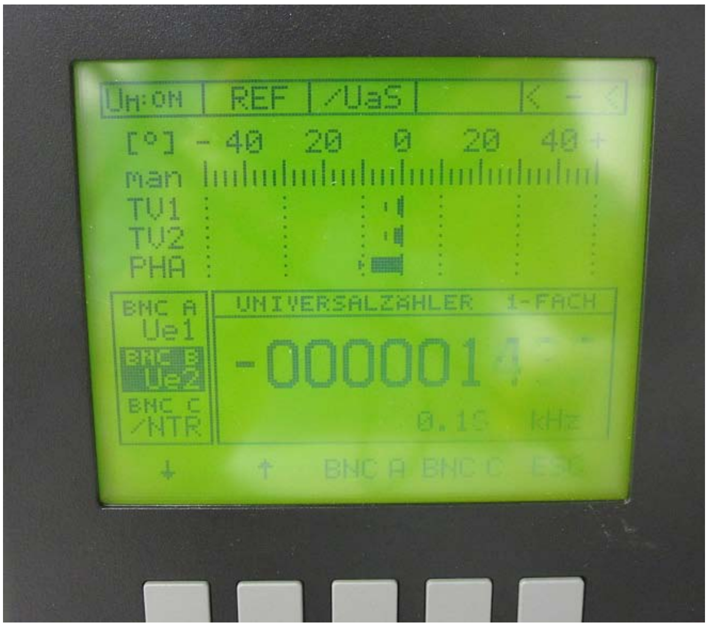
approximately equal magnitude with a phase difference of close to 90 degrees.



9. If the magnitude of either signal is lower than required (should be around 3Vp-p) then the following adjustments may improve the signal:
    a. Translate the encoder closer to the tape along the z-axis by adjusting the appropriate allen screw. Note that this is a risky adjustment as the encoder may hit the tape if moved too far.
    b. Rotate the encode head around the x-axis.

   The latter step (b.) is not likely to cause much change in amplitude. Remember that the amplitude of a pulse is related to the encoder head being at the correct distance from the tape to ensure a focal length that matches the distance to the receivers.

10. Observe the “PHA” bar graph on the PWM 8. This displays how far away from a 90 degrees phase offset the two encoder count signals (TV1 and TV2) are. To reduce this value, rotate the encoder around the y-axis. This is done by loosening one of the grab screws that secure a spring loaded bolt on one of the four corners of the holder.

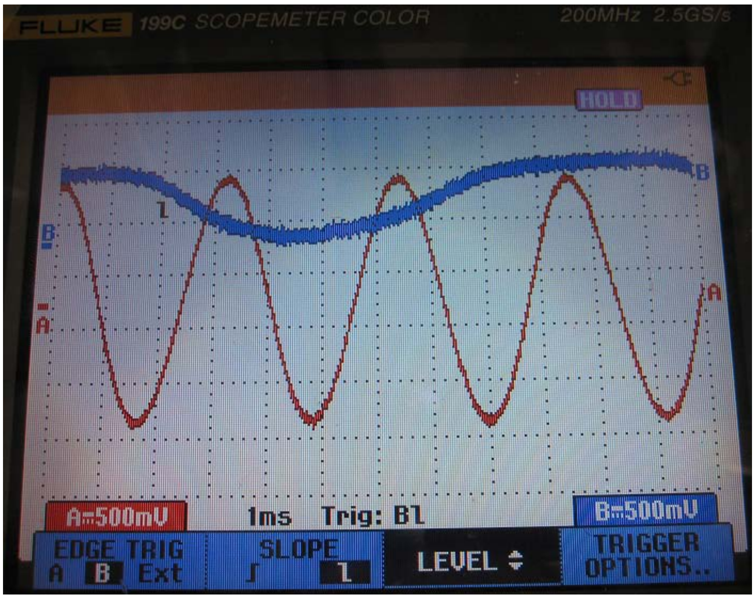


The phase value should be at least less than 20 degrees and preferably less than 10 degrees. Adjust accordingly.

11. Reconfigure the PWM 8 to output the Cref pulse (Ue0) on BNC A and the summed counter pulse (Ue1+2) on BNC B.

12. Set the trigger mode on the oscilloscope for Channel A (Cref channel) to trigger on a falling edge (Cref is active LOW). With a movement rate of 8 arcmin/sec this should trigger every 10-20 seconds. You may need to adjust the trigger level through experimentation.

13. Upon the triggering by a Cref pulse, observe the alignment of the signal “valley” with the steady sine wave of TV1+TV2. It is this alignment that we want to adjust so that the two signals are completely in phase. The main contributor to the phase of the two signals with respect to one another is the adjustment of the encoder head around the z-axis. Note that the phase is very sensitive to the adjustment of the head around this axis and so a movement of half or even a quarter turn may be all that is needed to shift the two signals into phase.



14. Verify that by making the above adjustments the phase between TV1 and TV2, indicated by "PHA" on the PWM 8, has not changed dramatically and is still within limits.

15. Repeat the above steps for each of the encoders on the axis (e.g. four for the Keck 1.8m telescope).

16. Carry out a variety of telescope movements to observe if the adjustments have produced positive effects (e.g. the absence of fatal following errors). If previous problems still exist, the solution may lie elsewhere such as in the gain values used in the feedback control of the telescope.